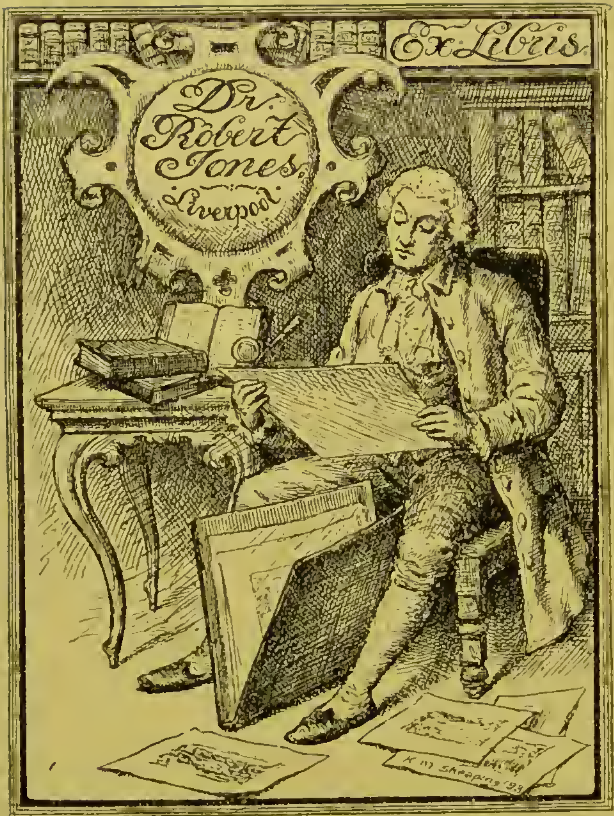

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The Mechanics of Lateral Curvature.

BY
HENRY O. FEISS, M.D.,
Cleveland.

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THE MECHANICS OF LATERAL CURVATURE.

First Paper: The Mechanical Tendencies of Posture in the Normal.

HENRY O. FEISS, M.D., CLEVELAND.

In this report we are investigating the laws of the tendencies resulting from postural attitudes, the work being a preliminary part of a study of the mechanics of lateral curvature. (The investigation of the mechanical relation of normal posture to scoliosis has very recently been advanced by Dr. Lovett and it is from this work that we get the clew to further study.)

Segmentation and Balance.

In all erect attitudes some effort is necessary to enable a person to stand alone and this effort is afforded by muscular power, but there are certain positions in which the muscular power may be reduced to a minimum and these are obtained by distributing the weight uniformly about a perpendicular line which passes through the center of gravity. (Parow, Horner.)

The body is, however, not a firm mass but consists of segments jointed together, one segment resting upon the other. To prevent the body from collapsing connection between segments must be rendered firm. This is done by tightening the tube of tissues connecting superimposed ones. Then to maintain the erect attitude the line of gravity must pass through the base of support. So in all postures in which balance is maintained there is a constant equilibration by means of shifting segments. (Rimmer, Herman.)

But whether for the sake of balance or not, the result of this segmental movement must mean that the tube of soft parts made

up of muscles, fasciæ and integument, and joining adjacent segments is subject to a constant change to tension, so that if one segment moves upon an underlying one, the fact that motion takes place means that the soft parts which connect them must be in greater tension on some sides than on others. So again in the maintenance of an erect attitude which is asymmetrical the tube of soft parts is subject to difference in tension in accordance with the amount of shifting of superimposed segments. In a word, the attainment and maintenance of all positions entails a firm tonicity and tension in those parts of the body in which the segments are most separated. (Zuckerkandl and Erben, Duchenne, Spencer.)

The Movements of the Spinal Column With the Thorax.

If we regard this part of the skeleton in its ligamentous state any motion of the dorsal column must imply a motion of the thorax, for although the spine by itself is an elastic column, its intimate connection with the thorax must give that part of the column a relative unity of action. In the first place the attach-

Fig. 1. Fick. The attachment of the ribs to a vertebra, seen from above.

ment of separate ribs is of such a nature as to render a movement of any one of the upper ten vertebræ impossible without carrying with it a rib, for each of these ribs is attached to a vertebral body and to its transverse process. (Fig. 1.) As each is also attached to the sternum by means of a firm cartilage, then a movement of a rib must imply a movement of the sternum, which again implies

movement of all the ribs attached thereto, for the sternum completes the thoracic basket anteriorly and establishes its unity. The nature of the separate rib attachment to the vertebral bodies is suggestive from another point of view, for the upper ten on each side are attached not to one body but to two adjoining ones, so that the movement of one vertebra by affecting the ribs attached must mean movement of the vertebræ above and below. Finally the intricate fashion in which the ligaments connect the ribs to the vertebræ and the vertebræ to each other must favor concurrent movement in this dorsal region. (Fig. 2.) In agreement with

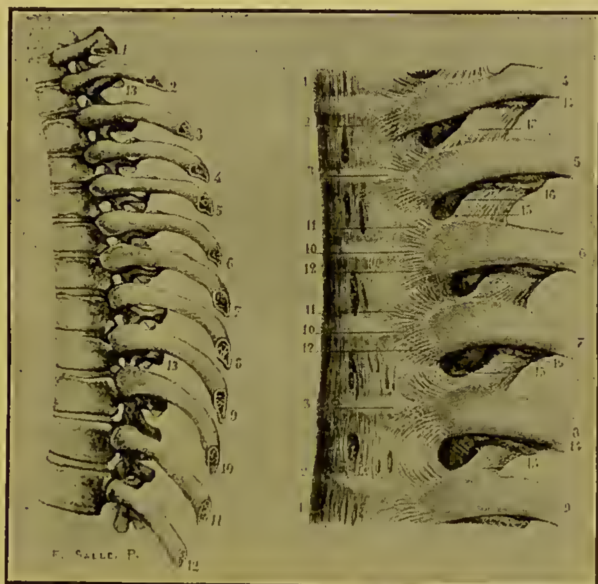

FIG. 2. Sappey's Anatomy. On the left the relation of individual ribs to the dorsal column. On the right the ligaments connecting the ribs with the vertebræ.

the above facts anatomical evidence shows little lateral and antero-posterior motion in the dorsal region (Guerin, Sappey, Quain, Hess) but most of the authorities (Volkman, Lovett, Quain, Schulthess, Menard and Guibal) agree on some intrinsic rotation theoretically possible here. As a matter of fact, however, the chief point at which rotation is carried out is the very lowest dorsal region, for the presence of the thorax interfering with the

individual vertebral movement, it can only take place where the vertebræ have little or nothing to do with the construction of the thorax. These requirements are offered in the region of the 11th and 12th dorsal vertebræ, for the ribs of these two are very short and do not attach to the sternum, they are not connected with the transverse processes of their respective vertebræ, and each is attached to one vertebra only. (Fig. 3.) In the lumbar region there are no ribs to interfere with rotation but the direction of the articular facets makes up for that, so that the only free motion here can be in the sagittal or lateral direction. Moreover

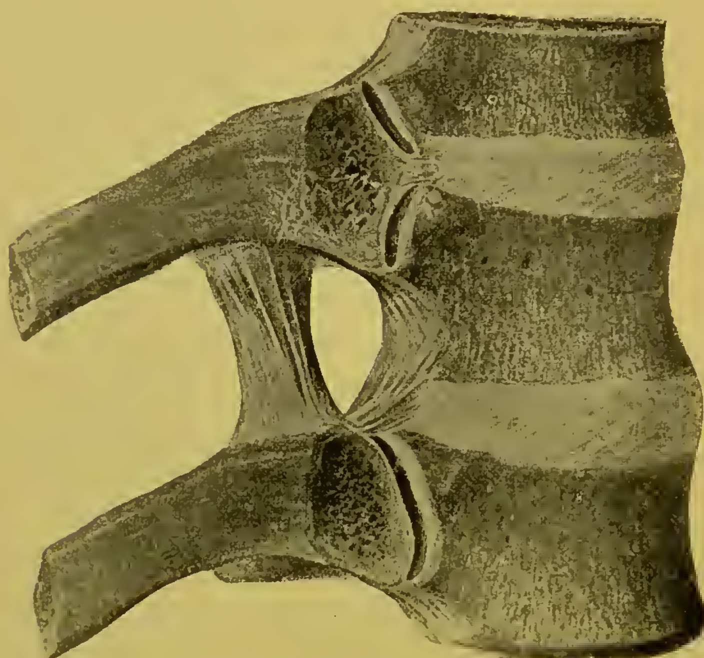

Fig. 3. Fick. The difference between the 10th and 11th ribs in their attachments to the vertebræ.

the change in the direction of the articular facets between the 11th and 12th is very radical for the lower facets of the 12th face like those of the lumbar vertebræ and the upper ones like those of the dorsal vertebræ. (Fig. 4.) This suggests a sudden change of function and we have to do with movement of the dorsal column

rather than movement in the dorsal column. Any individual vertebral lateral or rotatory movement which is possible in the dorsal region, except of course in the region of the 11th and 12th vertebræ, is only that dependent upon such play of the vertebral thoracic joints as is exemplified by breathing, but in breathing we think of a relatively fixed dorsal spine and the walls of the thorax moving in unison upwards and downwards by means of the swinging rotatory play of the ribs at the costovertebral joints.

Even if we assume considerable intrinsic movement in the

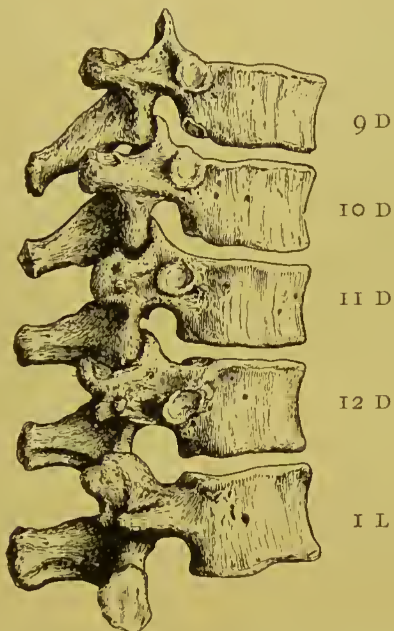

FIG. 4. Quain's Anatomy. 9th, 10th, 11th, 12th dorsal and 1st lumbar vertebræ. Shows the sudden change of direction of the articular facets in the 12th dorsal.

dorsal column, still relatively speaking, we may refer to its segmental motion, and the manner of the thoracic attachment gives this segmental motion a special significance.

The Trunk Muscles.

In considering the muscles of the trunk we have based our views upon the conception of G. Herman Meyer (Lehrbuch der

Physiologische Anatomie, 1856) who says, "If one leaves out of consideration the presence of the ribs and sternum, then the whole

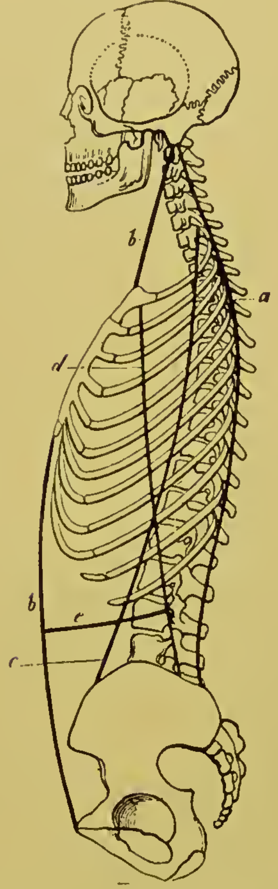

FIG. 5. G. Herman Meyer. The scheme of the trunk musculature indicating the direction of the various muscle pulls. a—posterior longitudinal muscle pull (m. sacrospinalis). b—anterior longitudinal muscle pull. c—oblique descending muscle pull. d—oblique ascending muscle pull. e—transverse muscle pull.

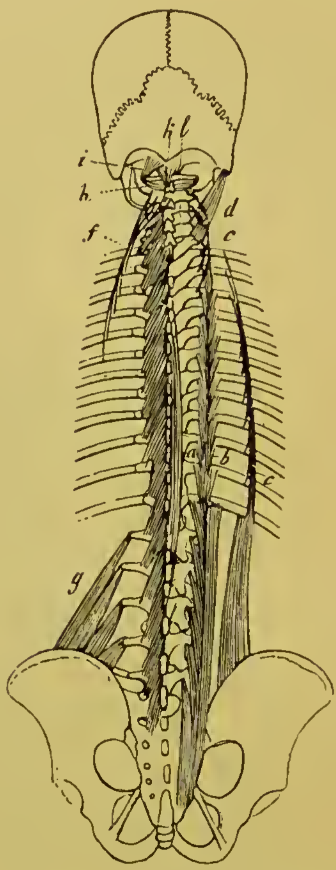

FIG. 6. G. Herman Meyer. The system of the sacrospinalis. a m., spinalis; b m., longissimus dorsi; c m., transversalis cervicis; d m., trachelomastoideus; e m., ileocostalis; f m., ascendens cervices; g m., ileolumbalis (hinder portion of m. quadratus lumborum Auct.); h m., obliquus capitis inferior; i m., obliquus capitis superior; k m., rectus capitis posterior major; l m., rectus capitis posterior minor.

trunk wall is to be regarded as a cylindrical or sac-shaped tube containing the viscera. The muscles which take part in the

fastening together of the same can only have the significance of furnishing a resistance against the pressure of the viscera or that of direct pressure on the viscera. In either circumstance this effect must be such a one as would diminish the tube in its diameter

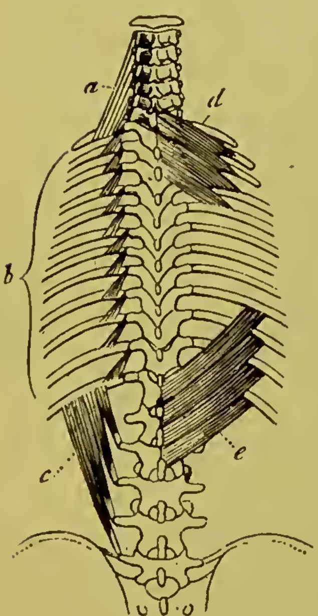

Fig. 7. G. Herman Meyer. The rib muscles. a m., scalenus colli. b m., levatores costarum. c m., scalenus lumborum. d m., serratus posterior superior. e m., serratus posterior inferior.

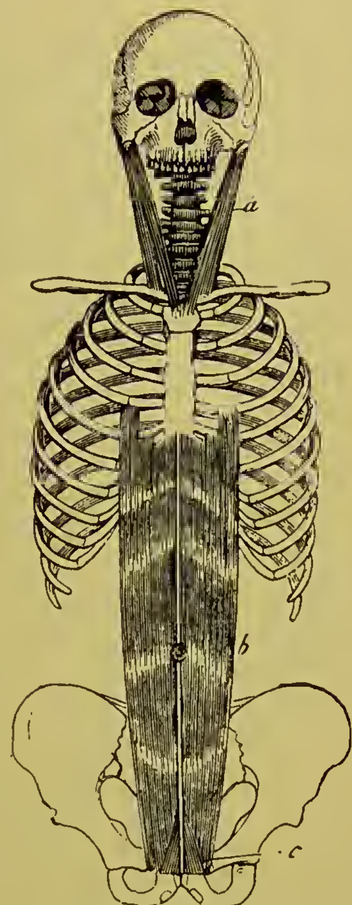

Fig. 8. G. Herman Meyer. Anterior longitudinal muscles of the trunk. a m., sternocleido-mastoideus. b m., rectus abdominis. c m., pyramidalis.

and therewith narrow the space present in the same." In using this system he divided the trunk muscles into five groups (Fig. 5). These are the posterior spinal system, the anterior spinal system, the two oblique systems which cross each other, and the trans-

verse system. The posterior spinal system begins at the occiput and ends at the pelvis. (Fig. 6.) In connection with this system we find a close muscular union of the thorax to the spinal column. (Fig. 7.) The anterior system begins in the neck with the sterno-

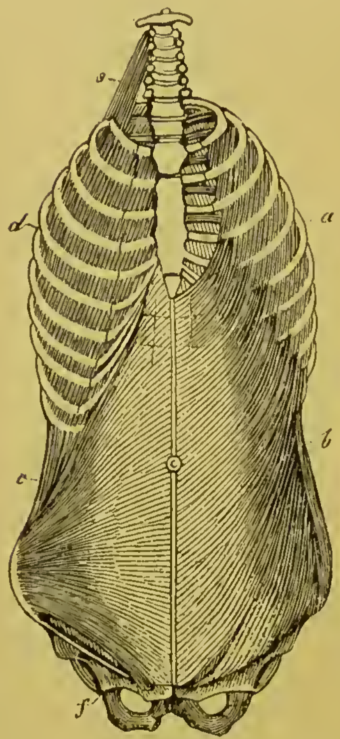

FIG. 9 G. Herman Meyer. The two oblique muscle pulls. On the left the descending oblique. a m., external intercostals; b m., descending oblique or externus abdominis. On the right the ascending oblique muscle pull. c m., descending oblique or internus abdominis; d m., internal intercostals; e m., scalenus colli; f m., cremaster.

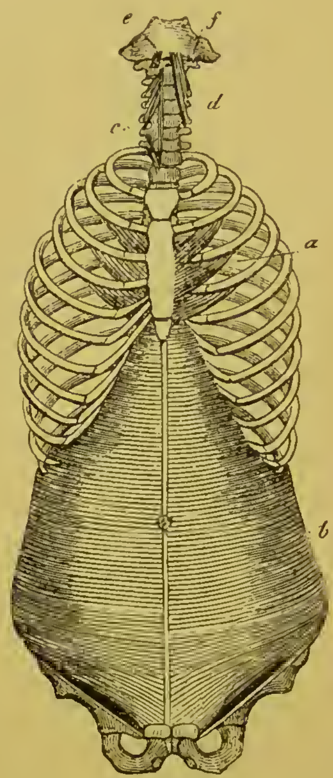

FIG. 10. G. Herman Meyer. The transverse muscle pull. a m., triangularis sterni; b m., transversus abdominis; c m., longus colli; d m., rectus capitis anterior major; e m., rectus capitis anterior minor; f m., rectus capitis lateralis.

cleido-mastoid and is continued from the sternum to the pubis in the shape of the two recti joined by the linea alba. (Fig. 8.) As to the two oblique systems he considers the external inter-

costals as continuous with the external oblique and the internal intercostals as continuous with the internal oblique, the difference in the region of the thorax being simply that the ribs form rigid interruptions. (Fig. 9.) The two pulls cross each other. The transverse system is that of the transversalis muscle which

FIG. 11. Normal boy standing erect.

encloses the front of the abdomen and bridges across the subcostal angle. (Fig. 10.)

According to this analysis the muscles of the chest are actually continuous with those of the abdomen, the only difference being the insertion of the rib bones in the upper part, so that the practical

distinction between abdominal and thoracic parietes is merely one of rigidity. Consequently a pull from any part of this tube will not stop at any particular rib, but will always be communicated

FIG. 12. Normal, bending to left.

to the one above so as finally to exert itself upon the total thoracic wall. (See also Quain, Schulthess, Zuckerkandl und Erben, Duchenne.)

STUDIES ON THE LIVING.

If we seek further interpretation of some of these facts we may resort to photographs of the normal. There are so many varieties

of posture that it is very difficult to pick out any especially important one. A pure bend only occurs by coincidence. In the same way with the pure twist. Nevertheless these two postures are perhaps the simplest for purposes of demonstration. It is to be remembered, however, that the camera only reveals integumentary shadows; what goes on under the skin is a matter of interpretation alone.

Fig. 13. Normal, twisting.

Fig. 11 shows the normal erect. Fig. 12 shows the effect of a side bend. The segmental movement of the thorax is quite manifest, and it is noticeable that it has swung with its base to the

right until it meets the resistance of the lateral factors. The hips are also swung to the right and so also are the knees. The right side of the body is drawn hard and tight, while the left is in folds. In this case which is one of almost pure lateral flexion a sharp bend is noticeable at the dorso-lumbar region. Of course if the

FIG. 14. Normal, bending sideward and forward and slightly twisted.

point of view had been somewhat to the left, there might have been some apparent dorsal curve. The tension on the right thoracic wall is a direct one, taking place on diametric opposition to the bending column and increasing in proportion to the bend. Fig. 13 represents the twist. The twist begins from the ankles,

includes the pelvis, and finally the thorax and shoulders. The soft parts connecting the thorax with the pelvis have become spirally tense. This tension has rotated the pelvis and even affected the knees, showing that the action is communicated from

FIG. 15. Normal from in front bending laterally.

one segment to the other. The tension on the thorax, however, is not a direct one like in lateral bend, for the two forces, the resistance in the ribs and the tightening of the tube, do not diametrically oppose each other. Fig. 14 shows the effect of forward

and lateral bend with a slight twist, giving the dorsal region an apparent lateral curve. The right pelvis is raised by means of the tightly drawn factors running from the thorax, and the length of the body is greater on one side than on the other. Again the right thoracic wall is under strain. Fig. 15 shows the effect of

FIG. 16. Composite of erect and lateral bend.

lateral bend from the front in another boy. The noticeable thing is the pendulum movement of the thorax, swinging as a segment within the tube of tissues with its base to the right and its apex to the left. This being a position of equipoise, segments are balanced over the base of support. Fig. 16 is a composite picture

after the method of Lovett, comparing the lateral movements in the previous figure with the erect without changing the foothold or camera. This figure shows the lengthening of the body on the right implying the increased tonicity of the muscles, and as

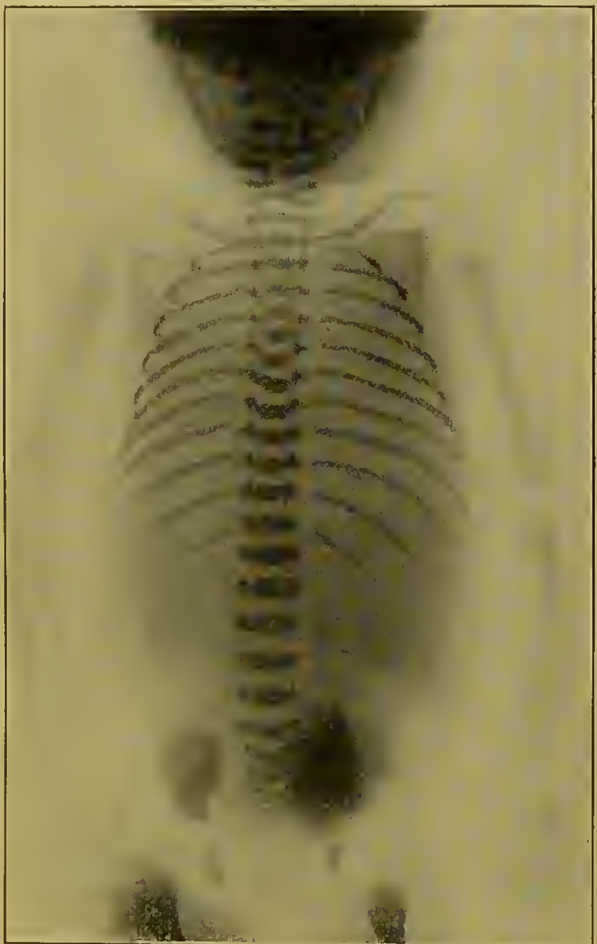

Fig. 17. Röntgengram of fetus laid straight.

Lovett points out the part taken by the entire body in a lateral bend. (Compare with Lovett, Guerin, Volkman, Weber Brothers.)

Röntgen Studies.

Fig. 17 shows a fetus laid straight on the negative. It happened that the thoracic cavities were not quite equal in breadth, the

right being smaller than the left. Fig. 18 shows the effect of bend to the right. The tension on the wall is so great that the left thoracic cavity, which beforehand was broader, is now become narrower than the other, for the tube of tissues running from the neck to the pelvis on that side being lengthened, is so stretched that the strain coming on the ribs has approximated the side wall

Fig. 18. Röntgengram of fetus bent sideways.

to the vertebral column, also it has caused the ribs on that side to separate and to descend, while on the opposite side they are more crowded together. Fig. 19. Twist. The relative distortion in taking such a picture is so difficult to measure that it is

not fair to estimate the size of the thoracic cavities, but the thing which is plain is that the tube of tissues does have at least a little effect upon the bony thorax. Fig. 20. This is a Röntgen picture of a three year old normal living child. The effect here is similar to that seen in the fetus in side bending—namely, narrowing of

Fig. 19. Röntgengram of fetus twisted.

the thorax on the convex side and separation and descent of the ribs, and crowding on the other. There seems to be some lateral bend in the dorsal column. This is at least partly due to the slight twist accompanying the bend. The maximum bend is however in the lowest dorsal region. Fig. 21. The effect of

side bending in a ten year old living boy, and the same effect is once more to be demonstrated.

Conception of Artists.

The expression of thought which stands on the highest plane is that conveyed by great artists, but we present the following cuts

Fig. 20. Röntgengram of three year old living child bent to side.

here less for their scientific value than as a matter of appropriate interest. The artist first conceives and then expresses, and this expression depicts not merely what he observes, but what he thinks, and if he sees no deeper than the skin, yet he tries to realize what is going on beneath. Then by accenting certain contours and shadows he may give us his thought. No camera can do this.

We have first to do with those artists who studied the physiology of motion chiefly from the living. These were the Greeks, who, having dissected little or not at all, nevertheless gave much time and thought to the human physique, as seen in athletic sports (Duval, Fletcher). Then we have to do with the later schools who based their conceptions, at least to a moderate degree, on their

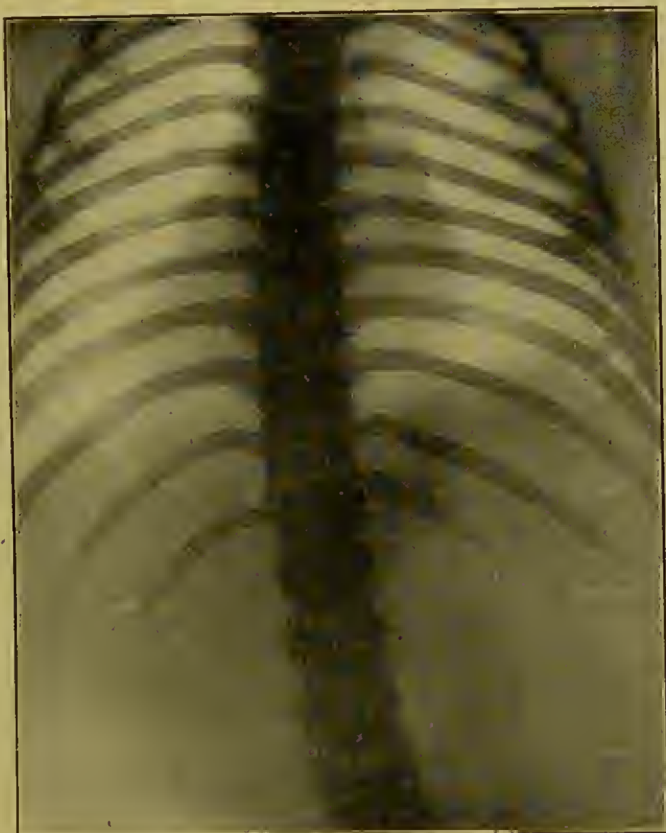

FIG. 21. Röntgengram of ten year old living boy bent to side.

knowledge of anatomy. This group is represented chiefly by Michaelangelo and Raphael, who made great use of their anatomical knowledge. (Critical essays of masters, Ruskin.) Leonardo DaVinci besides his vast anatomical learning made a careful study of the mechanics of motion and posture. (Leonardo DaVinci—Munz's edition, Richter's edition. Extracts from Leonardo's works.)

Fig. 22 from eastern pediment of Parthenon. Postural figure reclining on left thigh and pelvis. The trunk is bent upwards. The thorax is moved as a whole. The left lateral wall of the torso is in a state of extreme tension, straining the left thoracic wall and compressing its sides. The right wall of the thorax is not compressed and even flares out. The mid-thoracic line is practically straight but continuous with the mid-abdominal line.

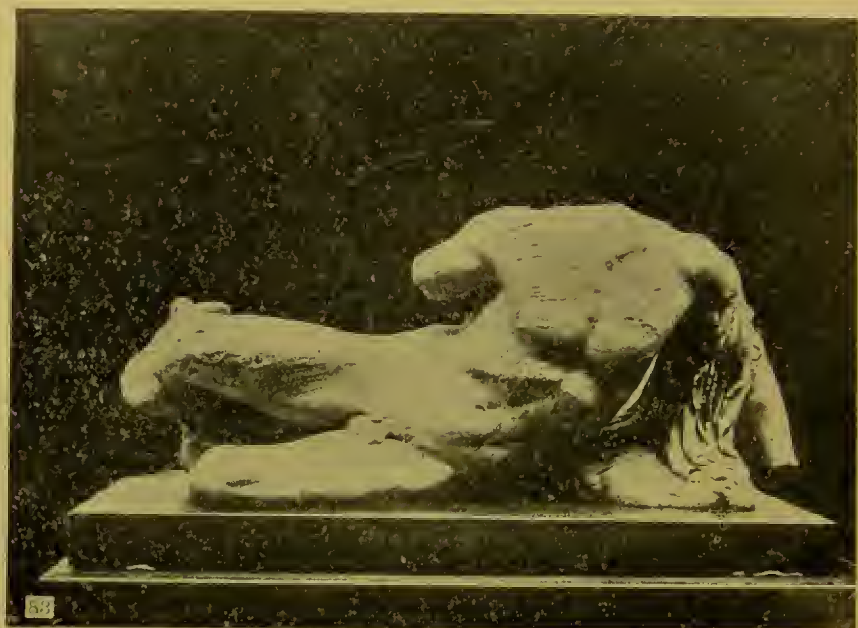

FIG. 22. Figure from Eastern Pediment.—British Museum.

Fig. 23. Laocoon. Middle figure in action. Torso bent to left. Thoracic segment bending as a unity, but with such force as to cause great strain on right thoracic wall. Left trunk shows a fold at the waist line.

Figure of boy in the right of the picture in strained posture. Thorax bent to the left. The strain is upon the right thoracic wall beginning at foot. The waist at the left thrown into folds.

Fig. 24. Farnese Hercules. Postural. The figure rests partly

on support. The thorax has shifted to the left. In this figure the left chest is under pressure and the right is relaxed. The mid-thoracic line is straight and at the ensiform the linea alba diverts from this towards the pubis showing the shifting of the chest as a unity.

The Wrestlers. Fig. 25. Figure on top in action. Trunk

Fig. 23. Laocoon.—Vatican.

bent forwards and thorax twisted, facing to the right. The thorax here has twisted considerably with respect to the pelvis. The total segment has bent and yet the line representing the spinous processes is continuous in a total curve with the lumbar spinous processes. The factors which are thrown into tension are

those on the right. From the shoulder to the buttocks the whole right chest is under compression owing to the tension. The left waist shows two folds of relaxation. Ribs here are not compressed.

Sketches by Leonardo DaVinci. Fig. 26. The figure in equilibrium and activity. Weight resting on right foot. The

Fig. 24. Farnese Hercules.—Vatican.

line of balance passes through upper part of thorax. Trunk bent to right. Right waist line folded and left side of torso in comparative tension. Fig. 27. Figure on left. Postural. Facing forwards. Weight on left shoulder conveyed into right foot. The thorax bent towards the right, its lower border swinging to the left, throwing into tension the left wall and relaxing the right

waist line. Figure on right. Weight on back conveyed through left foot. Tension doubtful on account of weight-bearing. In both figures the line of balance passes through the pit of the neck. Fig. 28. Figure on left. Figure twisting to the left. Right trunk wall taut. Left waist free. Figure on right. Twisted to the left and bent to left. Right shoulder high. Right and anterior

FIG. 25. The Wrestlers.—Uffizi.

trunk wall tight, apparently compressing right thorax. Left waist in folds. Fig. 29. Postural figure. The line of balance passes through the pit of the neck and weight resting on the left foot and left hip. Trunk bent to the left. Lower thoracic wall swung to right so that the right thoracic wall is under tension, while the waist is folded on the left. The arc from the pubis

to the pit of the neck represents the arc of the folds radiating from an imaginary center to the left of the figure. Fig. 30. Figure in activity. Line of balance through pit of neck. Figure rests

FIG. 26. Sketch by DaVinci. Trattato della Pittura.

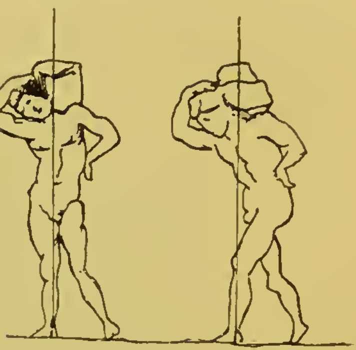

FIG. 27. Sketch by DaVinci. Trattato della Pittura.

on right foot and is twisted to the left. Both trunk walls under tension. Fig. 31. Dancing figure. Line of balance passes

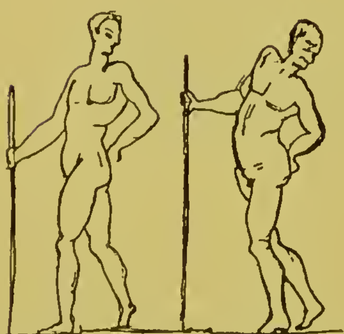

FIG. 28. Sketch by DaVinci. Trattato della Pittura.

FIG. 29. Sketch by DaVinci. Trattato della Pittura.

through pit of neck. Trunk bent to right and right waist in folds, while left trunk wall is greatly tightened from the foot to

the shoulder. Fig. 32. Postural figure. The line of balance through pit of neck. Resting on right hip and right foot. Left torso wall tight. Right waist concave. Thorax swung to left.

FIG. 30. Sketch by DaVinci. Trattato della Pittura.

FIG. 31. Sketch by DaVinci. Trattato della Pittura.

Fig. 33. Dancing figure. Great twist of thorax to the right showing great tension on all thoracic walls.

Michaelangelo sketch. Fig. 34. Figure with back. Shows

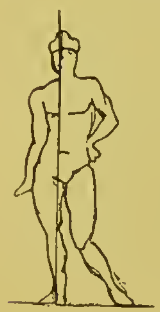

FIG. 32. Sketch by DaVinci. Trattato della Pittura.

FIG. 33. Sketch by DaVinci. Trattato della Pittura.

weight thrown on right hip and right foot. The head over right foot. Trunk bent to right from the pelvis. Thorax swung to left. Tightening of left trunk wall throwing right waist into folds. Although the thorax has moved as a whole the mid-spinal furrow has an apparent left lateral curve.

Fig. 35. Raphael. Figure on right. Weight on left foot. Head poised over this. Trunk twisted to the right but bent slightly backwards. Thorax conceived as a total thing. Left waist line considerably relaxed.

Fig. 36. Stuck. Compare with Michaelangelo's sketch.

Fig. 34. Study by Michaelangelo.

Thorax here shifted as a total segment upon the pelvis showing tension on left thorax wall and fold at right waist line. The lower border of the thorax has swung to the left.

General Conclusions.

The Effect of Movement on the Soft Parts.

The muscular system, the fasciæ and the skin forming an

enveloping layer from the neck down to the pelvis, any movement of the trunk must throw a part of this enveloping tube into tension. If, for example, the pelvis is fixed and the trunk bent to the side, then whatever be the primary source of movement, the convex side of the enveloping tube is immediately tightened by the mechan-

FIG. 35. Study by Raphael.

ical conditions of separation of the parts. Again if in equipoise posture the head is kept in the same relative position to the feet and the body bent to the side, it must imply a folding of the tissues on the concave side and a tension on the other side of all the factors running from the foot to the head.

In a twist, the enveloping tube running from the thorax to the pelvis is strained spirally until it is taut, the pelvis coming

with it until brought to a standstill by the muscles, fasciæ and ligaments which hold it to the thighs. The thighs and legs being fastened together by the stiffened knee-joints come still further

FIG. 36. Study by a recent painter. (Stuck.)

around on the ankles until the ligaments, muscles and fasciæ around these joints are made firm, so that whatever motion is made and whatever the cause of motion, there is always an element of tension in the soft parts which connect adjacent segments.

Effect on the Thorax.

In the thorax the greatest tension must come upon those factors to which this segment owes its maintenance of shape, namely, the ribs. In a side bend the tissues running over the thoracic wall on the convex side are immediately stretched, so that if there is any elasticity in the rib wall they will first give on that side. For as the body lengthens here the muscle wall will tend to approximate the bending column, and the more so in a position of equipoise, which would imply a pendulum motion of the thorax, its base swinging to the side of the convexity. This approximation of the side wall to the column is the important thing, for this means a direct strain upon the interposed rib wall, namely, the posterior part of the thorax in question. The tendency which follows would be for the angles of the ribs to become sharpened on that side. Besides this, on account of the stretching of the lateral wall, the ribs will separate in accordance with the amount of tension, and there will be a downward inclination compared with the ribs on the other side. On the side of the concavity the ribs become crowded together and there is no tendency to sharpen their angles.

In a twist the strain of the muscular resistances is transmitted through the circumference of the base uniformly so that the strain comes upon both halves of the thorax at approximately the same time. This would of course tend to a separation and a descent of the ribs on both sides. The separation of the base of the thorax from the pelvis is not of the same mechanical character as that in lateral bend, for in a lateral bend the direction of the tightening is diametrically opposed to the maintenance of shape of the thorax, while in twist, although the strain may come just as quickly, its direction is not directly antagonistic to the tendency to maintain the shape. Nevertheless there must ultimately be a great strain on the side walls of the thorax as the twisting column drives it through and against the resistances of the encompassing tube and the rows of ribs must tend to change their shape under the strain, although on account of the uniformity of the strain, actual change of shape may be little apparent.

The Effect on the Column.

If the ribs are under strain the effect of this strain must be further communicated to whatever is attached, namely, in this case back into the spinal column. Although the tendency to rib distortion is clear, the effect in the column itself cannot be easily demonstrated on the dead or on the living. In the dead, dissection is necessary, which destroys the normal conditions. In the living the bodies of the vertebræ are too far beneath the surface to permit accurate study. The Röntgen ray meets its limitation on account of the distortion, due to the fact that the rays come from one point. We therefore, will attempt to figure out the effect deductively and on a mechanical basis.

In the first place the region of the connection between column and ribs is the ~~bow~~ row of arches and the posterior parts of the bodies of the vertebræ (Fig. 1) and it is in this region that the effect of potential strain on the ribs must first be communicated. The important fact in a side bend is the approximation of the convex wall of the muscle tube to the spinal column or the reverse, tending to narrow that side of the body, so if in side bending the convex thoracic wall comes under strain and this strain is communicated from the ribs back into the spinal column at its posterior part, the row of arches, then while the ribs are sharpening and separating on that side, they must be conveying the strain into the posterior part of the vertebræ, so that this part will naturally tend to give in the direction of the strain; and the spinous processes are pushed in one direction while the fronts of the bodies of the vertebræ are approximating the bent wall in an opposite direction. In other words, while the total dorsal column is moving as a part of the thoracic segment, the strain brought to bear on the ribs is communicated back into the posterior part of the column as a separate tendency of reaction. This reactionary tendency in the column which we may designate as retrograde, is again counteracted in the normal by the firm connection of the anterior and posterior spinal ligaments, and by the inherent tendency of the dorsal column to maintain its unity.

In twisting the principles are the same but the effect is less direct. As a person twists, the soft parts running down the sides

of the thorax at the pelvis tighten, but tighten in a direction which is not directly opposed to the maintenance of shape of the thorax, so that we may not note any special local effect upon the thoracic walls. Nevertheless whether the actual shape changes much or not, the ribs do eventually come under strain and in the column itself this strain must fall once more upon the posterior part. Therefore, while the dorsal column is moving primarily with the segment of the thorax, its posterior part must tend to travel in a direction necessitated by the potential strain of the ribs, and this retrograde tendency, as in lateral bend, meets its resistance simply in the cohesiveness with which individual vertebræ are bound together.

REFERENCES ON THE PHYSIOLOGY OF TRUNK MOVEMENTS.

Schulthess, "Joachinstahl's Handbuch der Orthopadischen Chirurgie," 1905

Wiedersheim, R., "The Structure of Man," Translated by H. and M. Bernard, 1895.

Mann, L., "Centrallblatt für Nervenheilkunde und Psychiatrie," 1899.

Fletcher, Robert, "Anatomy and Art," 1894.

Zuckerkandl und Erben, "Wiener Klinischer Wochenschrift," 1898.

Owen, "Comparative Anatomy and Physiology of Vertebrates."

Hermann, "Lehrbuch der Physiologie."

Guerin, "Bulletin De L' Academie De Medicine," 2me Série, 1876 and 1877

Meyer, G. Hermann, "Lehrbuch der Phvsiologischen Anatomie," 1856.

Sappey, "Anatomie Descriptive," vol. i, ('88 Ed.).

Volkmann, A. W., "Virchow Patholog. Anatomie und Physiologie," No. 56.

Duval, "D'Anatomie Artistique."

Muntz, "Leonardo DaVinci."

Parow, W., "Virchow Patholog. Anatomie und Physiologie," 1864.

Quain's Anatomy, "Plan of Organization," "Segmentation of the Body," "Morphology of the Muscles," "Osteology."

Rimmer, W., "Art Anatomy."

Spencer, Herbert, "Principles of Biology," "The Shape of the Vertebrate Skeleton."

Weber, M. and E., "Mechanik der menschlichen Gehwerkzeuge," Göttingen, 1836.

Staffel, "Die menschlichen Haltungstypen und ihre Beziehungen zu den Rucksgratverkrummungen," Wiesbaden, 1889.

Menard and Guibal, "Gibbosite experimentelle," Revue de Orthop., No. 1, u. 2, 1900.

Fick, "Handbuch der Anatomie und Mechanik der Gelenke unter Berucksichtigung der bewegenden Muskeln," 1904.

Meyer, G. Herman, "Die Statik und Mechanik des menschlichen Knochengirüstes," 1873.

Duchenne, "Physiologie des Mouvements," 1867.

DaVinci, "Trattato della Pittura."

Ruskin, "Modern Painters."

Lovett, "Boston Med. and Surg. Jour.," June 14, 1900.

Lovett, " " " " " Aug. 6, 1903.

Lovett, " " " " " Sept. 28, 1905.

Hess, "Zeit. für Orth. Chir.," xiv Bd., 2 Heft.

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Mechanics of Lateral Curvature.

BY
HENRY O. FEISS, M. D.,
Cleveland, Ohio.

*REPRINTED FROM THE AMERICAN JOURNAL OF ORTHOPEDIC SURGERY
APRIL, 1907.*

PRINTED FOR THE AUTHOR.

MECHANICS OF LATERAL CURVATURE.

Second Paper: Demonstration of Models to Illustrate the Mechanical Tendencies of Posture in the Normal.

HENRY O. FEISS, M. D., CLEVELAND, OHIO.

In our first paper it was found that the laws of posture may be resolved into the fundamental laws of equilibration, and that these as they apply to the human form are most easily understood according to the conception of segmental motion. (With regard to segmental motion, although we laid stress upon the shifting of superimposed segments to attain or maintain any given posture, we did not make definite this division of the body into a precise number of segments because such segmentation as is required for movement or posture is not a perfectly formulated separation of the body into parts, for the shifting may take place at a number of variable points, adapting the length of segments to the requirements of a given attitude; for example, if a bend takes place from the pelvis, all the parts above may move as one segment if they are held rigid, but if additional bends take place in the neck and lumbar region the parts above the pelvis move as several segments. In the same way there may be a bend at the neck with rigidity of all the body beneath, or the neck might bend with an accompanying motion of the thorax or pelvis or both, so that the sharp limitation or the exact counting of the number of segments in the human body in the present connection must necessarily be impracticable, although the principle of motion must answer to this conception.) Such motion must apply to the skeleton alone but the totality of body form in any posture is established by the envelope of soft parts which rounds off the contours and exerts passive resistance upon the separated bony segments, as a result of which the skeletal parts are often under strain.

We further found that the thorax may be regarded as one of these segments and moving as a unit, either in combination or alone. This motion we referred to as primary and in this light the dorsal spine is to be regarded as an integral part of the thorax and moving as such.

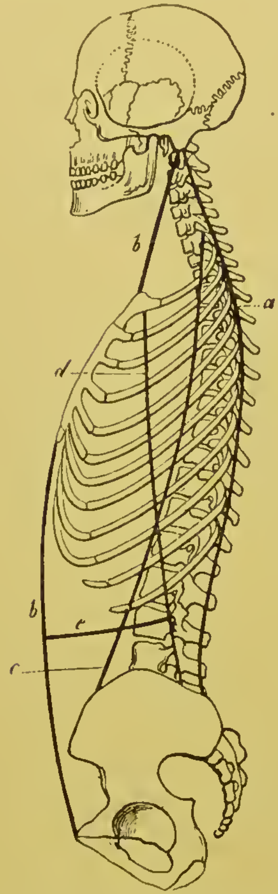

FIG. 1. G. Herman Meyer. The scheme of the torso musculature indicating the direction of the various muscle pulls. *a*, Posterior longitudinal muscle pull (*m*, sacrospinalis); *b*, nterior longitudinal muscle pull; *c*, oblique descending muscle pull; *d*, oblique ascending muscle pull; *e*, transverse muscle pull.

Then we showed that active movements of the thorax must imply tension of one or more of its walls, and the effect of such tension must be to place the ribs under strain, tending to change their shape and their direction.

Finally we attempted to explain on a deductive basis how the strain brought to bear on the ribs is conveyed back through their attachments into the dorsal column, and that the tendency of this must be to divert the vertebræ in accordance therewith, which tendency, as compared with the primary dorsal movement, must be regarded as a separate one of reaction.

To demonstrate more clearly our conception of these tendencies we have had mechanical models constructed. Regarded as evidence in favor of any theory they have little value, but we use them, not to prove but to illustrate, and if they do this we will feel satisfied that the purpose of their construction is answered.

These models were made by Mr. George H. Mickey, of Cleveland, and represent not merely a fine mechanical skill, but intelligent and deliberate thought during the act of construction. We take this opportunity of expressing our deep thanks for the work.

It will be remembered in our previous report that we laid stress upon the manner of regarding the muscles, for if the greater part of what we stated was based upon truth they must be looked upon

as functionating in two distinct mechanical ways, in the first place as conveyors of motion, and in the second place as passive factors of resistance. It is this latter function that we emphasize, although in this capacity they are not alone but simply part of the whole human machine, resembling more closely the fasciæ,

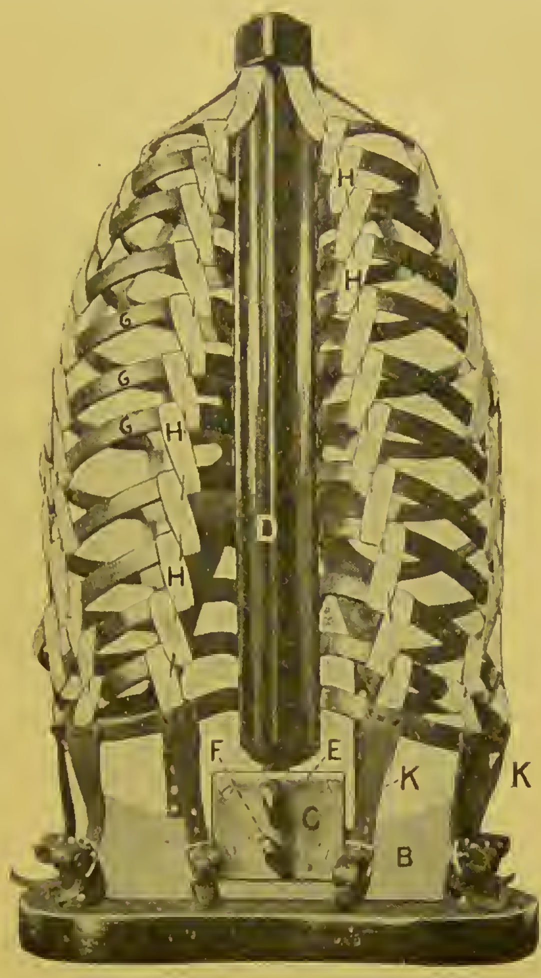

FIG. 2. Model of thorax, seen from behind. A, base; B, metal arc; C, block, gliding on arc; D, stave representing the dorsal column; E, set-screw fixing the ball and socket joint of dorsal column in block; F, set-screw fixing block to arc; GG, leather ribs; HH, tapes representing muscles; KK, adjustable leather straps.

ligaments and integument, but for the sake of simplicity it is only necessary to confine ourselves to the muscular system, for the other passive factors of resistance in any localized situation are closely interwoven therewith. We have already shown the peculiar

import of the trunk muscles and the aptness of Meyer's division in connection with this subject and therefore use his system (Fig. 1) as a guide.

Model of Thorax.

This (Figs. 2 and 3) consists of a base (A) representing a fixed basic resistance (either a fixed pelvis or the floor). On this is

Fig. 3. Model of thorax, seen from in front.

set an arc (B) made of metal, on which there glides a block (C); this block supports a curved stave of wood (D) made to simulate the shape of the dorsal spinal column. The connection between the block and the column is a ball and socket joint. This permits universal movement of the column upon the block in any position in which the latter is placed. There are two set-screws, one (E)

fixing the ball and socket joint and the other (F) fixing the gliding block to any part of the arc so that either one of the joints may be used without the other. From the dorsal column there branch out on each side twelve ribs (GG) made of sole leather and running into a leather sternum in front. Each rib has two attachments to the column, one to that part of the stave representing the row of

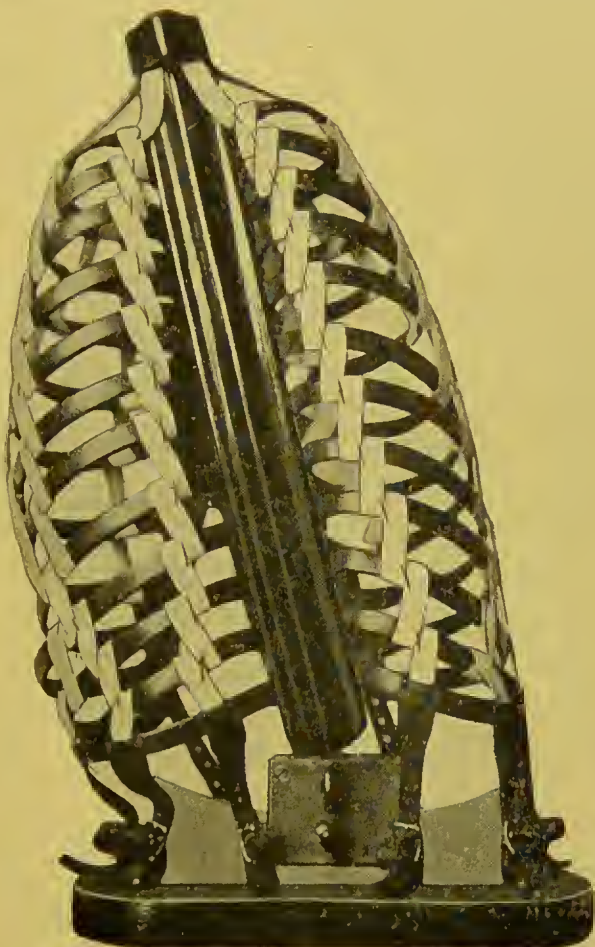

FIG. 4. Model of thorax. Pure side bend.

bodies, and one to that part representing the row of arches, thus imitating nature. The general relations and attachments are also designed to simulate the normal thorax.

Now using as a guide the diagram of Meyer which we mentioned, we attach tapes (HH) representing the muscular pulls as seen on his diagram. We have represented the longitudinal spinal muscles,

the external and internal obliques, the two recti, and the linea alba. (For purposes of simplicity we omit the transversalis.) These muscles, as we showed before, may be represented by a pull running from the walls of the thorax down to the pelvis. As to the nature of the application of each, we have simply passed the tapes from the upper attachments down the thoracic walls, fastening them to the ribs as they go down. These tapes are continued from the last ribs as soft leather straps (KK) which may be buckled to the proper degree of tightness at the base. So, a pull of any portion of the tapes is continued through the leather straps to meet its final resistance in the base. This sort of a thorax we have made to illustrate what we believe are the principal mechanical factors in the living. There is one hypothetical exception, the elasticity of the ribs. By using leather ribs instead of bone ribs we may trace out, in an exaggerated way, the path which the distortion would take and by means of such exaggeration hope to make clear what we believe the normal tendency is in the thorax. The stiff dorsal spine without any intervertebral joints is necessary to illustrate what we mean by total segmental movement of the thorax. In this way we are able to rule out all possibility of distortion in any other part than the rib wall. In other words, other things being equal, we hope to illustrate what effect total segmental movement of the thorax has upon a flexible rib wall under conditions of parietal resistance, resembling that of the normal tube of soft parts.

The first movement we deal with is lateral flexion. (Fig. 4.) To gain this the block is fixed to the center of the arc and the dorsal column bent to the side at the ball and socket joint which here is the center of motion. The immediate effect is a relaxation of the straps on the side towards which the column is bent and a tightening of the straps on the opposite side. The effect of this tightening is to compress the rib wall, to narrow that side of the thorax, sharpening the posterior convexities of those ribs, and causing them to descend.

The next position (Fig. 5) is one which more closely simulates the usual lateral bend, namely, a pendulum movement of the thorax, its base swinging to the right and its apex to the left, for unless

the pelvis is fixed, this is the position of normal side bending because it balances this segment over the base of support and so permits an easier equilibrium. (See previous report.) In the model this position is obtained by releasing both set-screws and sliding the block to the right on the arc, the arc representing no particular motion but simply the type of motion. (In this case

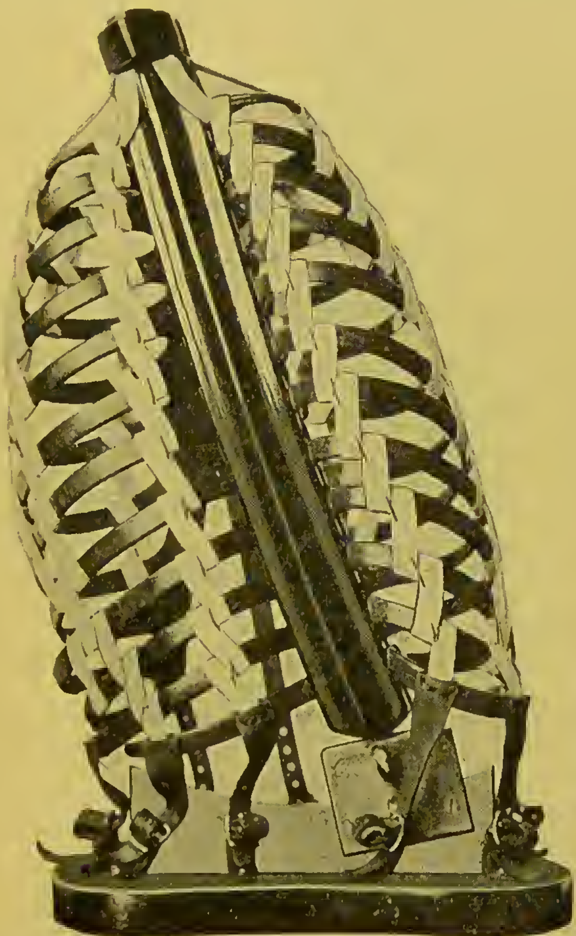

FIG. 5. Model of thorax. Side bend with base swinging on the arc.

the center of motion is a movable one and located, of course, above the arc.) The effect is the same as the previous one with the single difference that in the present position distortion is more pronounced, so that for practical purposes in side bending, whether the base swings or not, the illustrations are alike, namely, on the convex side of the bend an approximation of the vertebral column

to the lateral resistances, a narrowing of the thorax, a descent of the ribs, and a sharpening of their posterior curves, while on the other side we find marked relaxation.

The position of twist (Fig. 6) is gained by tightening the block on the arc and rotating the column on the ball and socket joint. The kyphotic curve of the column now becomes a lateral curve.

Fig. 6. Model of thorax. Twist.

A whirling arrangement of the muscle straps is shown very plainly, the anterior ones being directed obliquely in an opposite direction to the posterior ones and the same opposition being noticeable in the lateral straps. This shows that the basic portion of the thoracic wall may be rendered taut by the spiral pull. In the ribs there is little change of shape, the chief change being a flatten-

ing of the lower ribs on the concave side of the lateral bend of the column. But distortion is in no way marked. The difference between this and a lateral bend is that in twisting the column the tension is conveyed uniformly through the base and the effect is widely distributed throughout the thorax, while in a lateral bend the tension on the side of the convexity has a direct effect soon

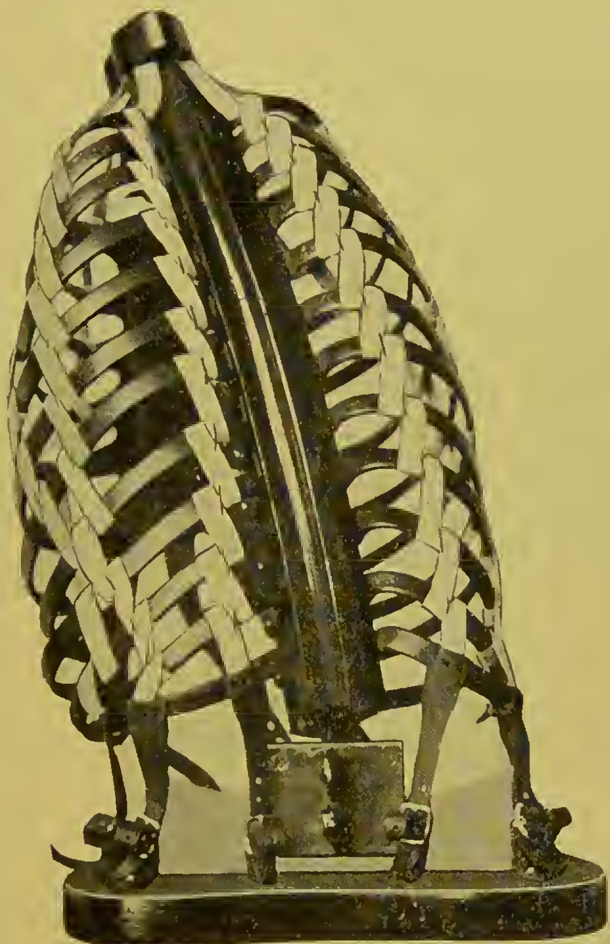

FIG. 7. Model of thorax. Twist, with side bend.

after the beginning of motion. As is to be expected, if we add to the twist any amount of lateral bend (Fig. 7) the effect of the lateral bend immediately becomes noticeable.

So the chief points illustrated in this model are, first, that with segmental motion of the thorax and with tissue resistances on the lateral walls, distortion will take place in the rib walls if there is

any elasticity present; second, that lateral bend has a direct tendency to distort them, and that twist has a less direct tendency to do so, probably on account of the more uniform strain through the base of the thorax.

Model of Vertebra and Rib.

In the previous model we only illustrated our views up to a certain point, ruling out all possibility of effect beyond that of rib distortion. The thing which we now have to illustrate is, what tendency, if any, rib distortion may lead to in the individual vertebra.

We found earlier that in spite of the propensity to total thoracic movement which is to be regarded as the primary motion, there may, nevertheless, be inherent possibility of motion between separate dorsal vertebræ, the nature of their motion being probably a rotatory one. (It will be noted that if we so often refer to a dorsal spine moving in conjunction with a unified thorax we cannot refer to a movement between separate dorsal vertebræ without seeming to contradict ourselves. In explanation we repeat what we stated earlier, that when we refer to a dorsal spine and its segmental motion we mean a practical condition, or, better, its motion regarded as relative to that of other parts of the body, so that the possibility of individual vertebral movement is perfectly consistent as taking place apart from the primary movement of the thorax.) Yet, even if we suppose that there is absolutely no movement between dorsal vertebræ in nature we may in our model apply a hypothetical amount of mobility for the simple purpose of demonstrating the tendencies under given conditions, but this model is made not so much to illustrate a vertebra and a rib as the relations between parts and the nature of the forces and the resistances brought to bear in a cross section of the thorax under conditions of normal posture.

We have to do, in the first place, with a rib ring, the interruption of the sternum being for theoretical purposes eliminated. The rib ring meets behind by means of the vertebral column, this interruption being afforded by the kidney-like shaping of the rib ring, for in nature the rib ends, instead of meeting, run almost parallel

to each other to their respective attachments on each side of the vertebræ.

Our model (Fig. 8) consists of a solid base (A) with a white strip (B) to denote its median. Upon this base there glides a

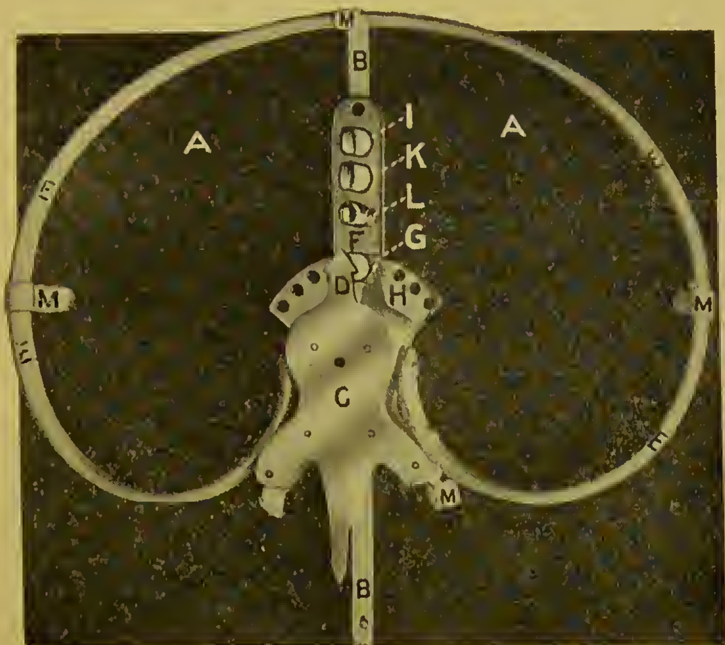

FIG. 8. Model of vertebra and rib. A, base; B, median strip; C, vertebra; D, arrow, indicating direction in which the vertebra points; E, leather rib; F, steel axis on which vertebra is pivoted; G, retaining peg, holding arc of vertebra to steel axis; H, metal arc fastened to base of vertebra; I K, fixation pegs passing through steel axis into base; MM, elastic tapes representing the muscles.

wooden vertebral segment (C) faced with metal. This is prolonged into an arrow (D) to indicate the direction in which the vertebra points. To the posterior part of the body and the transverse processes of the vertebra is attached a leather ring (E) in the manner described above. To carry out the principle of segmental motion we use a steel axis (F) to represent the primary radius and have attached the vertebra to it by means of a pivot (unseen in figure). Then by using a retaining peg (G) which fits into a steel arc (H) belonging to the vertebra, the two axes, the vertebral and the primary, may be rendered one if we pass the peg through the central hole of the vertebral arc as seen in Fig. 8. In this way the

vertebral motion may be made part of the primary segmental motion; but by removing the retaining peg the vertebra is permitted to revolve on its own axis. By means of two fixation pegs (I K) which pass through holes in the steel primary and fit into holes in the base, we can fix this axis in a number of asymmetrical positions. A handle (L) enables easier manipulation. Our muscular resistances are represented by elastic tapes (MM), an anterior elastic representing the linea alba and the recti, two lateral elastics representing the oblique muscles, one on each side, and two posterior elastics representing the posterior spinal muscles.

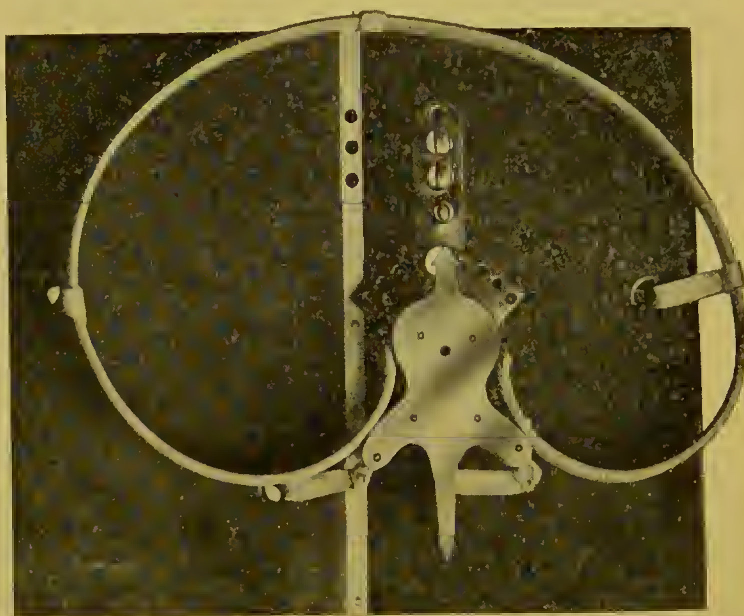

Fig. 9. Model of vertebra and rib. Side bend, the retaining peg in place.

Taking first the pure lateral bend to the left, then the total segment of the thorax would either make a pendulum motion, so that the apex would go to the left and the base to the right, or the whole thorax would swing to the left as shown in the previous model. In either case the important point is the approximation of the convex rib wall to the column. We now obtain a position analogous to that seen in Fig. 5 which we believe illustrates the characteristic type. With the retaining peg in place at the center of the vertebral arc we pass the steel axis laterally to the right and apply the two fixation pegs to hold it in its position. (Fig. 9.) This

brings about a tension in the elastics on the right. The result is, of course, a distortion corresponding to that in the previous model (Fig. 5), an approximation of the vertebra to the side wall on the right, with narrowing of the area between, and posterior arching of the rib. (To demonstrate a position analogous to a pure side bend as in Fig. 4, it would be necessary, instead of passing the primary axis to the right, to compress the right rib wall by pulling the right elastic towards the left, which would, of course, bring about practically the same effect as the above, but with the

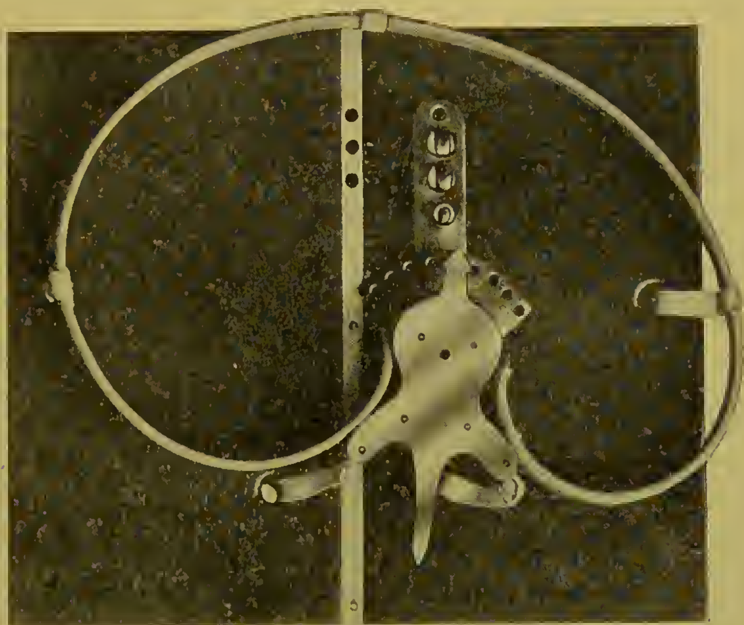

FIG. 10. Model of vertebra and rib. Side bend, retaining peg removed.

vertebra and rib ring in a different position on the base. But this would require clumsy illustration, and as it is not the position of usual lateral bend and the effect is so similar to the other it will not be necessary to dwell longer on this phase.)

The next step is to release the vertebra so it has the power to gain a new equilibrium, providing there is any potential energy in the distorted rib wall. To demonstrate this (Fig. 10) we remove the retaining peg, releasing the vertebra, and immediately the arrow diverts from the axis of primary motion, or what is more important, the arrow diverts toward the side on which the rib is the more convex posteriorly, namely, in this case towards the right.

Now taking the twist, first placing the vertebra so that its arrow points in a line with the primary axis and with the retaining peg in place to hold it there, then by twisting the axis on one fixation peg in the median line, and applying the other after it is twisted, we have in this way been able to divert the primary axis and the vertebra as one piece (see Fig. 11), and this illustrates the position of the vertebra when regarded as moving as part of the segmental motion of the twisting thorax. We recognize that the condition of the rib ring so far as shape goes corresponds to that of the total

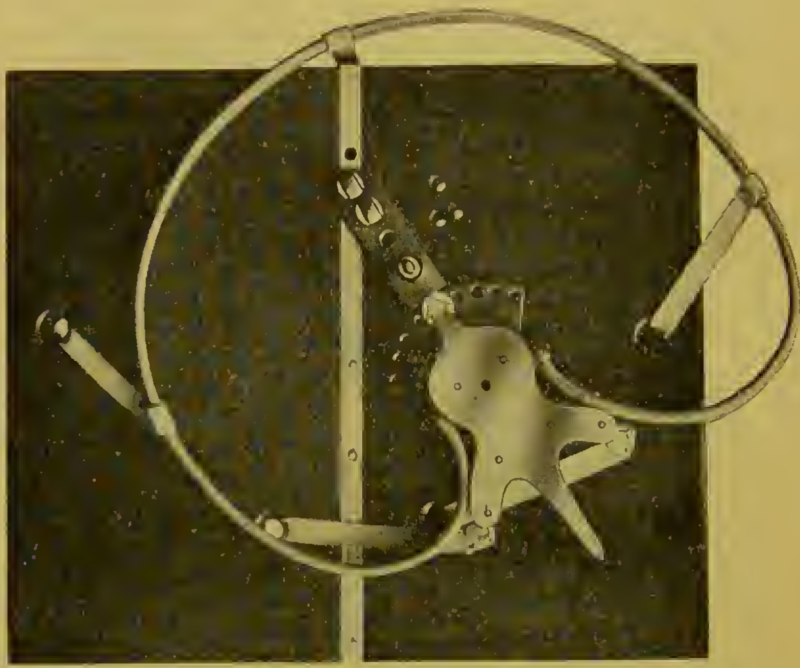

FIG. 11. Model of vertebra and rib. Twist, retaining peg in place.

thorax in the previous model here seen in horizontal section, for all we have done is simply to have moved the whole thing, vertebra and ribs attached, as one piece. It is also to be noted that all the elastics are under tension in a peculiarly spiral manner and that this tension does not affect the shape of the rib ring beyond a moderate degree, owing to the distribution of the pull. This is in marked contradistinction to that effect noticed in the first position of lateral bend (Fig. 9).

To demonstrate the final tendency, the next step (Fig. 12) is to

remove the retaining peg from the arc of the vertebra so that it may move on its own axis if it has such a tendency. The effect is marked, for immediately the arrow diverts a good part of the arc to the right. This permits the right rib to obtain a great sharpening posteriorly compared to that of the left, and the tension on the elastic straps is diminished or disappears entirely, showing that the whole machine has gained a new equilibrium. It is very interesting to note that this final position corresponds very closely to the final position of the lateral bend, although the primary axes

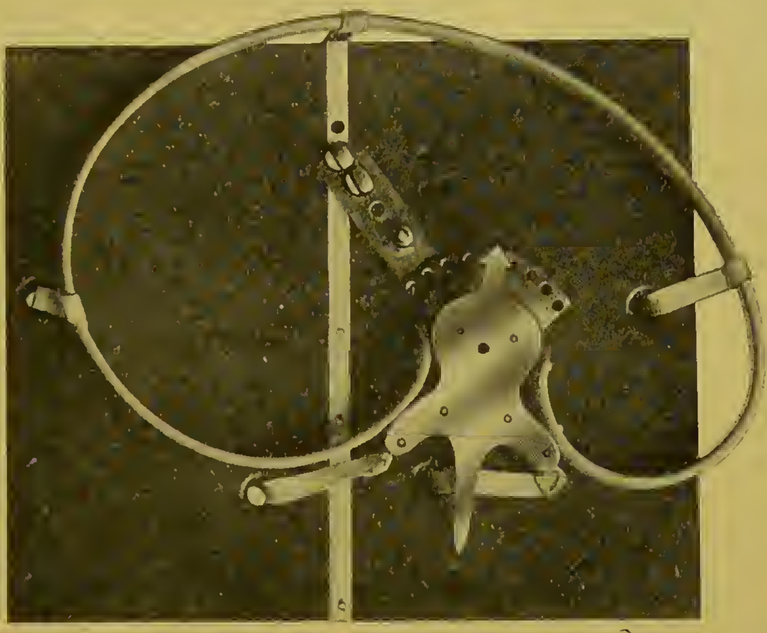

FIG. 12. Model of vertebra and rib. Twist, retaining peg removed.

are in different positions (compare Fig. 10 with Fig. 12). That is to say, the shape of the rib and the direction in which the vertebræ are pointing with reference to the median line of the base are practically alike in the two. We must also add here, although it is not necessary to illustrate the point, that we have taken the primary axis and placed its center of motion behind the vertebra instead of in front, then we moved the vertebra to the right and released it again after the manner of the previous illustration and we again could obtain a similar position to that of the final position of lateral bend or twist. In the same way we placed the center

at other points which permitted us to get the same result, the point of the arrow always diverting toward that side on which the rib becomes more convex posteriorly. (It is also to be noted that the arrow may point in a direction which diverts from the median line one way while it diverts from the primary in the opposite way. For example, we may place the primary axis in such a position that the arrow will point to its left while it may still point toward the right of the direction of the median line, but the law which it follows is with reference to the direction of the median line.) In short, if the vertebra is allowed to rotate freely, its direction and the shape of the ribs attached are practically the same by whatever path its center reaches a certain point, the final position being simply one of equilibrium. This fact explains how immaterial it is to decide on a fixed position for the center of motion of the thoracic segment, the important point being to discriminate from such primary segmental motion and any movement which might possibly take place in an individual vertebra.

Of course it can readily be understood that the cause of the mechanical alterations observed in the position of final equilibrium is principally in the parietal resistances but they are influenced also to a marked degree by the peculiar relation of the vertebral ends of the ribs to the posterior part of the vertebra; however, the ultimate distortion is not the result of any one thing but is the result of the sum of all these conditions, namely, the relation of parts, the attachment of the pulls, and the elasticity of the ribs. Therefore, the chief points illustrated in this model are, first, that in asymmetrical movements, a dorsal vertebra will tend to move upon its own axis, which is entirely distinct from the axis of motion of the thoracic segment; second, that the vertebral axis will tend to divert (from the direction of the median line of the base) toward the side on which the posterior curve of the rib presents the greater convexity; and third, that the factors which control these tendencies, namely, the parietal resistances of the rib ring, the peculiar relation of the ends of the ribs to the back part of the vertebra and the elasticity of the ribs, are fixed quantities so that the path tending to any given final distortion may be one of several.

So we have illustrated what we believe are the laws of the nor-

mal tendencies in the thorax. The quality and quantity of motion existing between separate vertebræ are points which are difficult to demonstrate definitely in nature. That there is a normal amount of movability, chiefly rotatory and perhaps lateral, there can be no question, and while we cannot analyze this motion accurately the effect of the tendencies under the conditions of strain illustrated must be practically the same. But even if there were not the slightest movability between the vertebræ of the dorsal column and no effect could be obtained in the normal, the illustrations of the forces would still hold good, and we will later attempt to show that with such forces, active under given conditions of strain and fixation, any permanent distorting effect must follow the laws of the normal tendencies.

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The Mechanics of Lateral Curvature.

BY
HENRY O. FEISS, M.D.,
Cleveland, Ohio.

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THE MECHANICS OF LATERAL CURVATURE.

Third Paper: Evolvement of a Theory for the Explanation of the Condition, Based upon the Mechanical Tendencies of Posture in the Normal.

HENRY O. FEISS, CLEVELAND, OHIO.

Presented at the American Orthopedic Association at Washington, D. C., May, 1907.

In dealing with the subject of the mechanics of lateral curvature we have previously prepared two papers (American Journal of Orthopedic Surgery, July, 1906, April, 1907), in the first dealing with the tendencies to mechanical changes conduced by varied conditions of normal posture, and in the second illustrating certain conclusions pertaining especially to the thorax by means of mechanical models.

It will be noted that we have not yet touched upon the subject of lateral curvature proper, having so far only dealt with the normal, but we believe that the inferences so arrived at are sufficiently suggestive to justify us in reaching out for a hypothesis dealing with the main subject in hand, and the object of the present paper is to advance such a hypothesis, one which will offer to explain how, under given conditions of strain and fixation certain permanent distorting effects are answerable to the normal tendencies as previously deduced. We will not be able to formulate our theory in so many words at the beginning but can only select certain points from the earlier deductions which will serve as clues to direct us into the proper path. As we advance, however, we hope that the evidence will crystallize into a completer theory which may explain the more involved points even while it approaches completion.

Following are the laws of normal tendencies conduced by posture as derived from the earlier paper.

The Laws of Normal Tendencies.

First (Segmentation and Balance). The human body may be regarded as consisting of shifting segments which are supported with least effort according as the weight of each is distributed about the line of gravity.

(We use the term segment not in the sense of the comparative anatomist, who applies it synonymously to somite or metamere, thus referring to the repetition of similar structural elements in a longitudinal series, but we use it in its untechnical and simplest meaning, where small parts of a larger piece act together as one piece. If we turn to the chapter on Segregation in Herbert Spencer's "First Principles" we find the term segregate applied pretty much in a similar sense, but his term segregate does *not* quite fulfil our purpose, because he applies it to an actual coalescence where we refer simply to a functional coalescence, or perhaps better, a functional affinity, where groups of somites act together without necessarily fusing together. So we had better cling to the use of the term segment.)

Second (Peripheral Strain). All nonsymmetrical diversions of individual segments imply increase in tension in some or all of the peripheral strata, on account of the mechanical separation of the parts. This is true whether the attitude requires much effort or not. Consequently, attitudes of rest if asymmetrical may nevertheless be attitudes of peripheral strain (passive).

Third (Rib Distortion). The dorso-lumbar intersection in the spinal column being a region of great movability or adaptation, the thorax is permitted to move as a segment and if it is regarded so, then according to the second law enunciated, diversion of the thorax must mean that its walls come under strain on account of the peripheral tension of the soft parts. Consequently movements of the thorax must strain the ribs, tending to change their shape and their direction.

Fourth (Vertebral Retrogression). Such strains in the ribs must be communicated back into the dorsal column, implying a

tendency to a re-direction of its parts to accord with the re-arrangement of forces. Thus on account of the peculiar relationship of the ribs to the posterior parts of the vertebræ it follows as a mechanical consequent that the vertebral bodies will tend to retrograde in opposition to the direction of the primary peripheral

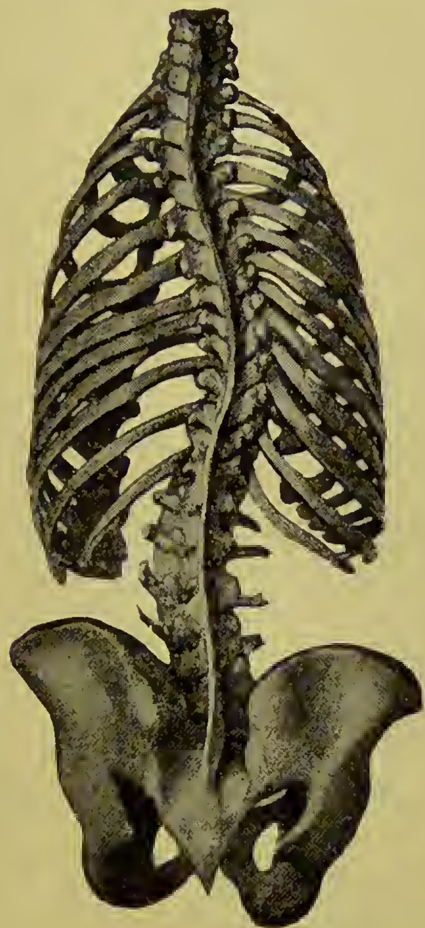

Fig. 1. From Whitman (Pfeiffer). Scoliotic specimen, showing distortions of thorax.

strains as expressed in rib distortion. So we see that the same strain which tends to distort the ribs also renders them levers for diverting the vertebræ.

These were the points as they applied to the thorax which we illustrated by means of the two mechanical models, one showing the relation of the soft parts to the thorax, regarded as a unity, and the other showing the tendency to a re-direction of individual

vertebræ regarded as separate points for attack by the leverage force and the potential strain in the ribs. Broadly speaking, they both illustrate the adaptation of structure to the forces brought to bear, showing that each new relationship or new shape acquired implies a tendency toward an equilibration of parts to conform with these forces.

How a Normal Tendency Results in a Pathologic Fact.

If now a normal structure is subject to such stresses as we have described, then it must possess some property which ultimately

Fig. 2. (Hoffa.) Scoliotic specimen, showing direction of sternum.

offers a counteraction to them, as must be implied if the structure is to remain normal. This counteraction is nothing more, or less than the internal resistance called forth by the attacking force. This internal resistance is furnished both by the relationship of parts, and by the cohesiveness of the material. When a structure has such a property it is spoken of as having elasticity and it simply means that it will resume its original form when the force is removed. This is true, however, only up to a certain limit, beyond which the structure will not resume its original form upon the removal of the force, but will be permanently distorted. The

point where this permanent distortion begins is spoken of as the elastic limit.

Let us illustrate. Take a beam of wood or metal and bend it a slight amount. It will, if immediately released, regain its orig-

FIG. 3. (Hoffa.) Spinal column of scoliotic specimen.

inal shape. If, however, the beam is bent the same amount and held in that position for a sufficiently long period, then if released, it will present a very slight bend; or if a very slight rhythmic bending is applied to the same beam many hundreds of times always

in the same direction, we will again find that if this is continued long enough the beam will not be in its original shape in the end.

We understand that according to the most authoritative versions such a change in shape following prolonged or oft repeated stress is best explained on a physical basis by the fundamental law of equilibration to which we have already alluded. As it applies here it simply means that the substance assumes a molecular re-arrangement until equilibrated to the stress.

How this physical law is modified by conditions of growth and

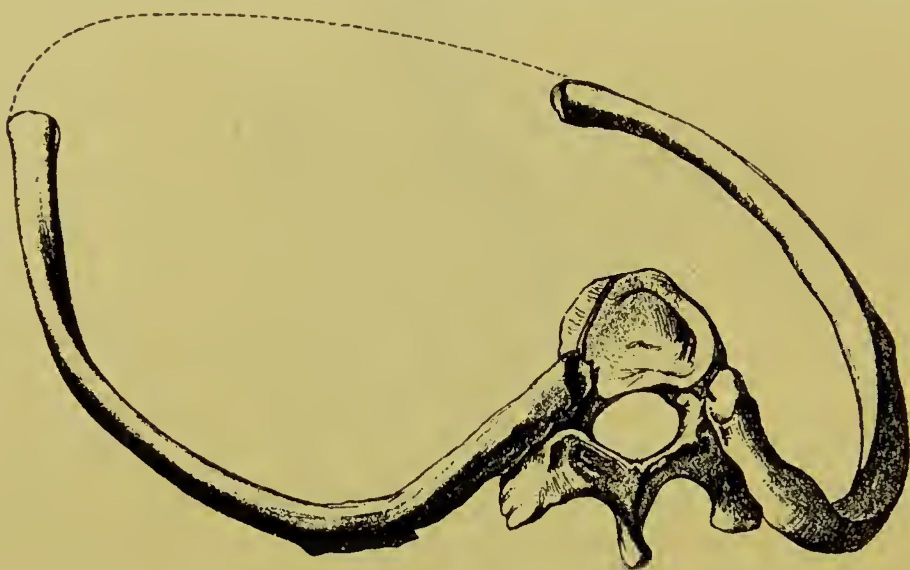

FIG. 4. (Lorenz.) Preparation of vertebra with rib ring, from scoliotic specimen.

development of living bone, is the deep question which we must leave untouched until we have more accurately stated our formula of belief (later report). For the purpose in hand we need simply assume that if bone is matter belonging to the universal cosmos, then whether it is living or dead, it will always be answerable to fundamental mechanical laws and if the law of equilibration applies, the living substance like any other substance will re-arrange itself in the direction of diminished resistance until a new balance is established.

In the present connection if we assume that our conception of strains in terms of distortion is correct, then we may further assume that just such distortion becomes permanent if the strain is car-

ried beyond the limits of elasticity, and as prolonged or repeated strain can bring this about we may readily understand how a normal tendency results in a pathologic fact.

So far then if we may briefly recapitulate, we have beeen chiefly concerned with investigating those laws which control the shape and structure by presupposing physiologic impulses which can only affect the shape and structure up to the normal limits of elasticity so that there will be a return to the original condition when the strain ceases. If we are now able to make a hypothesis which

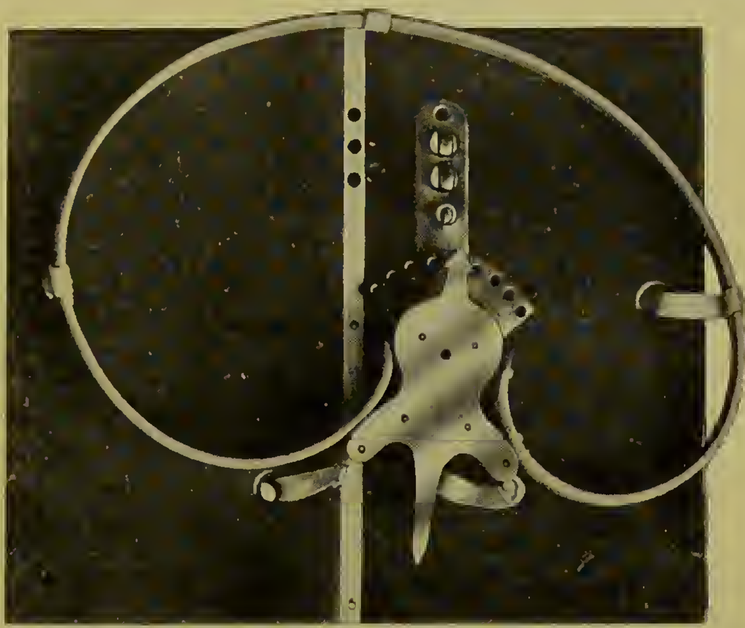

FIG. 5. Final position of cross section model. Compare with Fig. 4.

is to explain certain permanent distortions, we must assume a strain which does not permit a return to the original, thus applying a derangement beyond the limits of elasticity or the establishment of a new limit.

The first step in developing our hypothesis* must be to glance

* In dealing with the subject we express our views not without regard to other men's works, but for the present without specific reference to them. However, anything we have to advance is not given out in the hope of making good any claims to priority. We simply find we can express ourselves more unconfusedly if the views of other men are not alluded to for the time being. Moreover, lack of space prevents us from doing full justice to that literature and we hope that in some later essay we will be able to show a relation between other works and our own.

over the important deviations from the normal which are found in the ultimate distortions of the pathologic subject. As others have

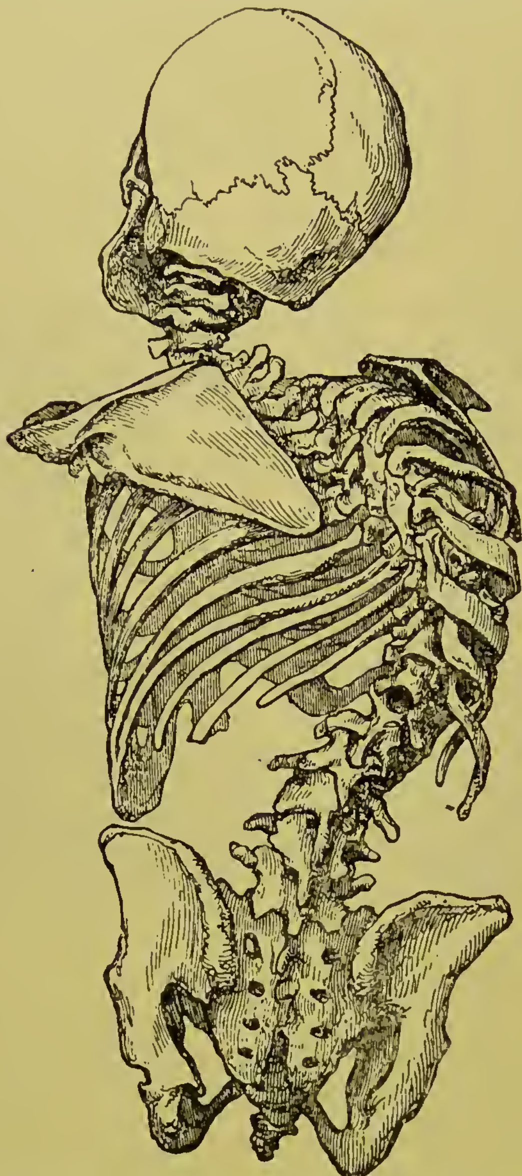

Fig. 6. (Chance.) Scoliotic specimen showing angulation of ribs.

done we will regard the skeleton chiefly, as the findings here are the most important and the easiest understood.

Chief Distortions of Scoliotic Specimen.

If we take a specimen of scoliosis of a rather common type

which for the present may be regarded as typical, we will find, besides the general asymmetry, certain characteristic changes of contour. This most common type presents as a marked distinction a posterior prominence and lateral descent of the ribs on one side, usually on the right. The appearance here is as though the thoracic wall had been forcibly crushed in towards the spinal column, flattening it on that side and sharpening the posterior

FIG. 7. (Hoffa.) Dorsal vertebra from scoliotic specimen with right dorsal curve, showing traveling of arch in relation to the body, lengthening of right pedicle and the approximation of the right transverse process to the spinous process.

convexities. (Fig. 1.) On the other side the ribs are deep and hollowed behind, but as a rule prominent in front. The sternum is about vertical although it often diverges slightly with its lower end either towards the left or right. (Fig. 2.)

Regarding the column by itself we note that there is a curve in the dorsal region convex towards the side on which the ribs are prominent, and convex towards the opposite side in the cervical and lumbar regions. It is very important to note that the bodies of the vertebræ usually form a greater curve than the spinous processes,

so that in the dorsal region they front towards the side of the dorsal convexity, while in the cervical and lumbar regions they front in the opposite direction. In a word, the bodies of the vertebræ (Fig. 3) may be referred to as pointing to the side of the convexity of the curve. Of course the change in direction from the dorsal to the adjoining regions is gradual, so that in the intervals they face in an intermediate direction.

(These are the most prominent points in the pathological specimen and will be sufficient for a start. The other points we will not describe at present, as their descriptions will go hand in hand with their explanation.)

Explanation of Distortions Directly Answerable to Normal Tendencies.

If we try to find in such a specimen described any evidence which might be based directly upon the laws of normal tendencies, we must look first to the rib distortion, namely, the prominence on one side of the ribs posteriorly and the bulging on the other side anteriorly, these points being in perfect correspondence to the distortion which might take place if regarded as a tendency of posture not counteracted by normal resistances. We have dwelt on this point in full in the previous reports, and showed how postures of bend or twist implied tension on the side walls of the thorax, which must tend to culminate in just such distortion as found in the specimen. (See third law.) We must also expect to find as a correlative effect, that some of the vertebræ connected with the misshapen ribs point to the side of greater posterior rib convexity. (See fourth law.) In the skeleton this point is absolutely clear, and if we compare a horizontal preparation of a scoliotic thorax (Fig. 4) with the cross section model (Fig. 5) in its final distortion, the similarity is seen to be most striking, remembering that the final distortion of either lateral bend or twist as illustrated in that model may be practically the same.

We will also expect that the ribs which show the greatest malformation would be those offering the best leverage to the lateral resistances, so that we would look to the longest ribs as manifesting the greatest distortion and as causing the greatest retrogression to

correspond. These things are borne out by examination of the specimen which shows that the greatest retrogression and rib distortion are in the middorsal region, where the longest ribs occur. For the same reason we might expect little retrogression in the highest dorsal vertebræ and also little change of shape in the ribs attached, because they are proportionately thick and short. As to the eleventh and twelfth ribs they are unconnected with the sternum, and only having one attachment each to the vertebræ are quite adaptable to change of posture and could show but slight deformation. These things are borne out in the pathologic specimen.

The direction of the sternum would seem to be the natural one for it to take according to our analysis of the forces, and the lower part of the sternum being attached to the longest ribs must feel the greatest effect of the rib deformation because of the fact that these ribs bend the most, so that, as a result, their anterior ends must travel the most, while on the other hand the upper part of the sternum being attached to the immovable and shorter ribs, and thus being situated in the more stable part of the thorax, can feel very little the effect in the ribs. So we find a traveling of the lower end of the sternum in the path of least resistance, and its final position really represents a digression compared with its original position in the thoracic basket.

We must next refer to the descent of the ribs on the side of convexity (Fig. 1). This would seem to be a direct deformation due to the lateral resistances brought to bear, as we have shown in the model of the thorax in the previous report, and the ribs give in this direction as a result of the same strain as the one which makes them more convex posteriorly. (See third law.) But if the ribs acted strictly according to the laws of normal tendency in their descent they ought to be more separated peripherally, as shown in the Röntgen pictures of the normal in the first report. This would be true in the pathologic specimen if it were not for an additional fact of deformation, namely, as was first pointed out by Meyer, that they give at their angles, bending in the up and down plane (Fig. 6). As a result of this they become more crowded rather than more separated.

There is other evidence closely allied which is of suggestive interest. If the external surfaces of the ribs are subject to the tension of the soft parts by which they are covered, then we ought to picture them as forming one surface which is acted upon entirely and together. Then if we conceive the stress of the lateral resistances applied to a lateral surface of the thorax, such a picture must imply a maintenance of the total surface of that side even after compression has taken place, and this again must imply that each of the exposed ribs has twisted. Examination of the pathologic specimen seems to bear out this inference. So, as a result of the same tendency we have not merely a horizontal compression of the ribs and a bend near the angle, but an apparent twist in each rib. This point, so far as we know, is not mentioned in the literature, and it seems to us one of importance because it demonstrates quite graphically the application of a broad and unified stress.

Regarding next the individual dorsal vertebræ, we may again demonstrate evidence of pathologic changes directly answerable to uncounteracted normal tendencies. Here, if we assume a pressure such as might be conceived as brought to bear on the posterior part of the vertebræ as a result of the leverage and potential strain in the ribs, we ought to find some marks of distortion representing this pressure. Studying such an isolated dorsal vertebræ (Fig. 7) we find that the transverse process on the side of the convexity (right side in Fig. 7) is more closely approximated to the spinous process than the other. We also find that the pedicle is elongated on that side, implying a broadening of the vertebral foramen corresponding to the lengthening. These points are brought out in Fig. 4 more forcibly, the total effect being that the so-called arch of the vertebræ, made up of pedicles and laminæ, has been pushed to the left with respect to the body as a result of the strain in the right rib, during which process, and as a correlative effect, the transverse process to which the rib is attached has been bent in the direction of lesser resistance.

Plate I is a semidiagrammatic representation of the transformation from the normal to the ultimate shape resulting in this process. The upper diagrams give a view of the effect of two rib rings as

seen from behind, showing in the vertebræ, the retrogression, and in the ribs, the vertical angulation, the maintenance of the curve of the external surfaces, and the implied twist; the lower diagrams give a view of the effect in the rib ring as seen from above, showing

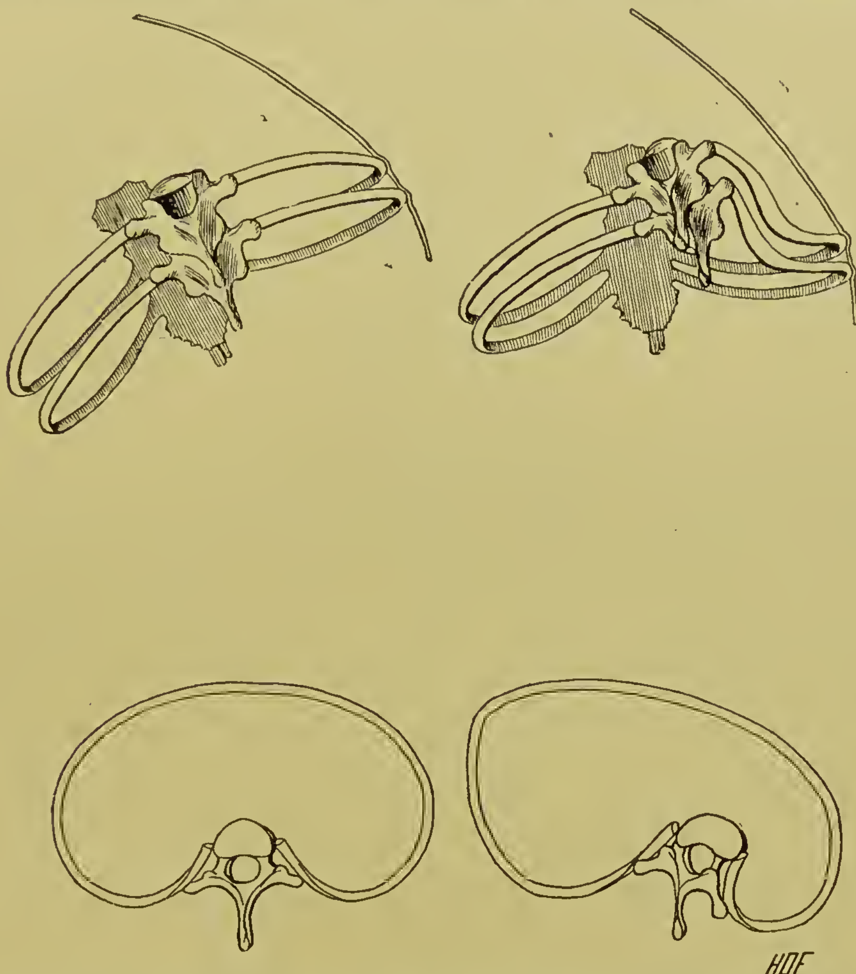

PLATE I. Semi-diagrammatic views of vertebræ and ribs attached with and without distorting strain. Upper figures represent posterior view, showing the angulation of the ribs following lateral strain compared with the normal. Lower figures represent view from above of same rib rings, showing the distorting effect in the rib and the changes in the shape of the vertebra following strain, also compared with the normal.

the transformation of shape of the posterior part of the vertebra and the horizontal compression in the ribs as expressed by the increased posterior convexity on the right side, and the increased anterior convexity on the left.

Thus far we have tried to explain how certain deviations from

the normal might take place directly on the grounds of postural tendencies, uncounteracted by normal resistances ~~tendencies~~. Starting now with such evidence we may further advance our theory and attempt to explain the more involved points.

The essential point you will want to see demonstrated is the formation of the lateral curve as running parallel with the deformation of the ribs and the allied phenomena already considered. This lateral curve in the column may be regarded as taking place not according to any one given formula, but as developing in different ways. But many of them represent not so much different principles, as simply different points of view. It is only for the sake of completeness that we detail some of the formulæ as separate processes.

Explanation of the Lateral Curve.

In selecting a plan which will cover the ground systematically we have chosen that of making diagrams, starting with the normal and constructing the scoliotic synthetically. Before demonstrating these diagrams, an introductory word is necessary. As we are trying to explain how posture may result in deformity by assuming that certain postures imply strain, we may conceive that any attitude is either one of strain or nonstrain; for no matter what the strain brought to bear it must be interrupted at some time or other. Then if we picture the attitude of strain as one of deformation and the attitude of non-strain as one of recovery, then all attitudes must come under one of these two categories, and so here it will be very satisfactory to guide our hypothesis from this point of view, and each of the following diagrams will fall under one of these two heads, belonging to the process either of deformation or recovery.

Deformation from Lateral Bend.

Starting now with the normal (Diagram 1) we first picture a phase of deformation in which the dorsal column moves as part of the segmental motion of the thorax and in which almost no actual bend takes place in this part of the column. According to the laws of normal tendencies, the ribs will give on the side of the convexity, becoming more prominent posteriorly and descending on

Diagrams (H. O. F.) to illustrate the transformation of the curve in the spinal column from the normal to the scoliotic, each representing an isolated phase either of deformation or recovery. (The tips of the spinous processes are connected by a heavy line to indicate the lateral curve as externally apparent.)

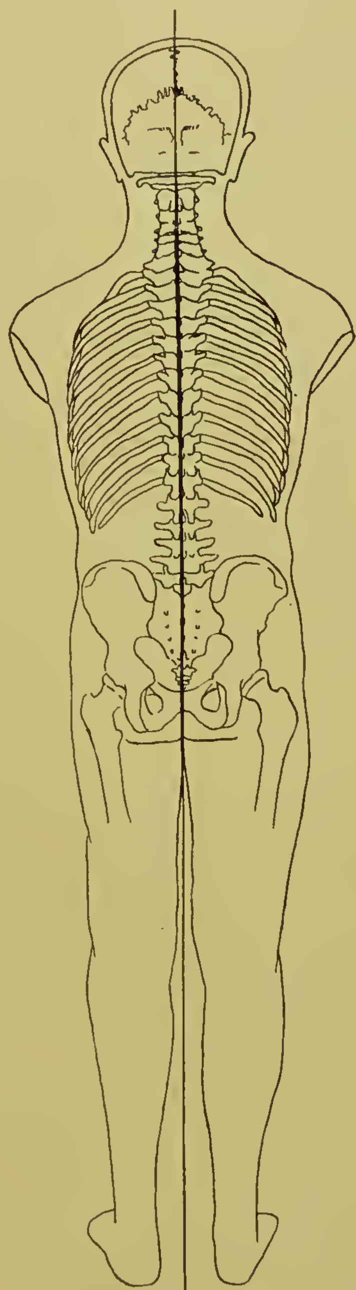

DIAGRAM I. Normal erect.

that side. The dorsal vertebræ will have retrograded slightly. The total effect is an approximation of the lateral rib wall of the convex side to the spinal column (Diagram 2). Supposing now the limit of elasticity is overstepped in the ribs so that their deformation is partially or totally retained, and let the patient recover from his bent position. He may recover either in segments or by treating the whole upper part of the body as one piece, thus maintaining the deformation relations of the upper segments to each other. In either case it is assumed that the rib deformations are maintained.

Taking the first alternative for recovery, namely, where the patient comes back segmentally, and he re-assumes practically the old relations but with the rib distortions preserved, we will note as a striking effect the approximation of the lateral rib wall to the column, and therefore the narrowing of that side of the thorax (Diagram 3). It will thus be seen that the figure is out of balance. The lines *a b* and *c d* are lines of gravity drawn as lateral tangents to the thorax in the plane of the paper. It is seen that the line *a b* passes outside of the pelvis and the line *c d* passes inside the pelvis. So it is not an unreasonable inference that there will be a tendency for the patient to shift his thorax over so that its horizontal contours will distribute themselves more evenly over the contours of the underlying parts; but what is more important is that the weight of the chest can be distributed much more equally around the line of support by some such shift of the thorax as this (see first law) because the weight of the narrowed side cannot possibly be equal to the weight of the broadened side. If you allow that this equilibration is carried out then you must further allow that the vertebræ to which the contracted ribs are attached must be dragged from the straight line which they originally formed, toward the side toward which the thorax shifts, because without such accommodation in the spine no shift could take place. Hence as a result of equilibration during recovery we have a lateral curve.

In the diagram the dotted line represents the lateral contour of the chest if it gets into some such equilibrium, which, as we have just shown, must imply a curve in the spinal column perhaps as represented in either of the two accompanying curves on the

LATERAL BEND.

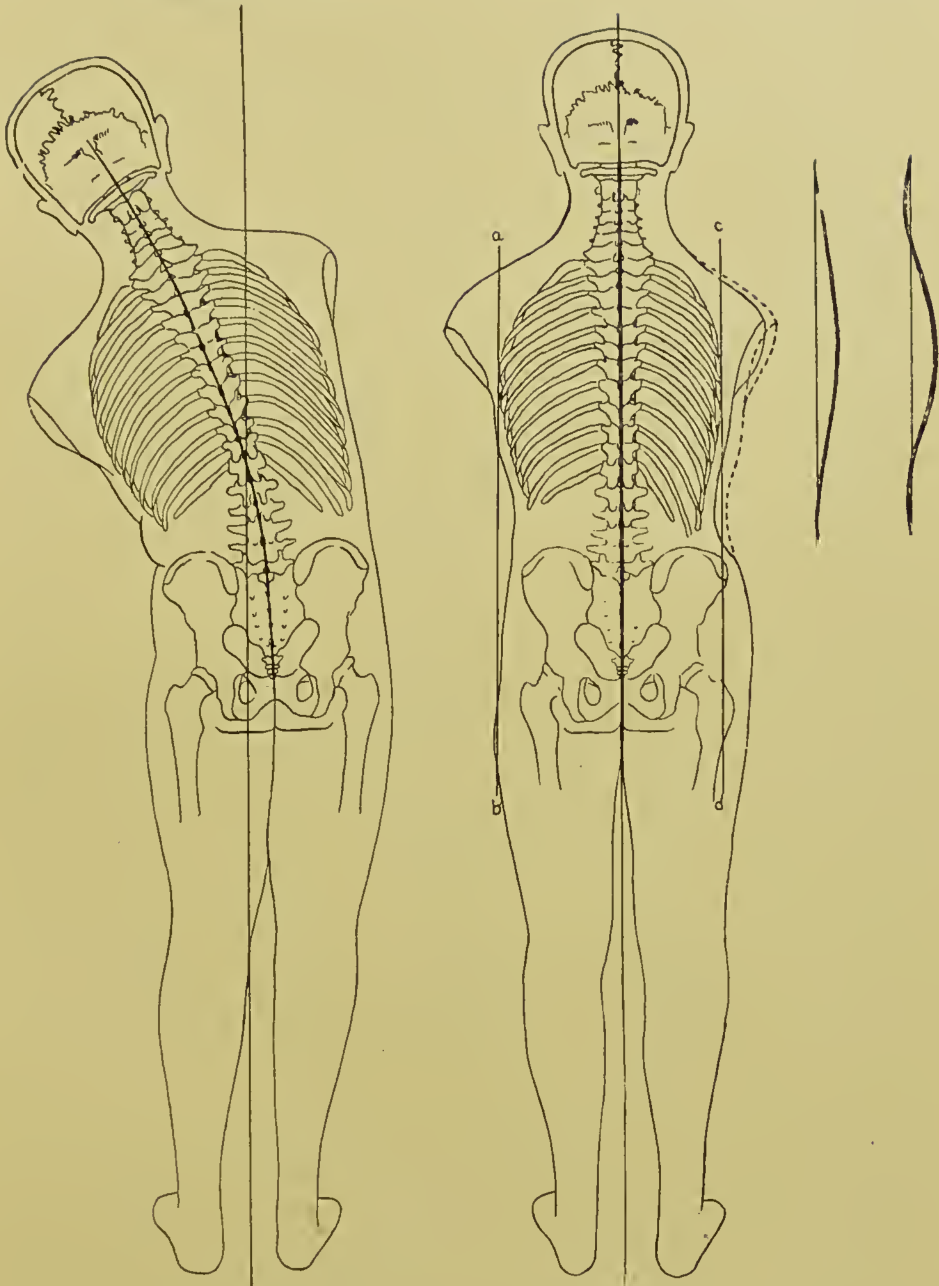

DIAGRAM 2.   DIAGRAM 3.

DIAGRAM 2. Deformation. Bend to side. Rib distortion on the convex side. Line of spinous processes makes one long curve. Retrogression of dorsal vertebræ.

DIAGRAM 3. Recovery from 2 without bend in spine (segmental). The only change here from deformation is the distortion of the chest wall with the accompanying retrogression of dorsal vertebræ. The lines a b and c d

right of the diagram, that is, either simple or compound. Such a shift cannot carry the head with it because the center of weight of the head must tend to remain over the line of balance for the same reason that the center of weight of the thorax tends to approach the line.

Taking the second alternative, recovery of the whole upper part of the body as one piece, then the position might be one such as might be gained by bending the knee (Diagram 4 A). The segments of head, neck, thorax, and pelvis have preserved their deformation relations, Diagram 2 and Diagram 4 A, being exactly the same except for the bent knee. Supposing now he goes on to the adjustment of these segments into equilibrium according to his present conditions. He will first straighten his head to get his eyes on a level, for that is, *a priori*, an instinctive tendency, and then he will attempt to level his pelvis by straightening his knee.

But as he levels his head and pelvis he must do so with reference to the thorax which has now become asymmetrized by the deformation, and he does this according to the same principle as demonstrated in the previous diagram. So if we draw tangents to the thorax and pelvis, and in the present example assume that these must become about equidistant to each other on each side for proper distribution of weight, then a lateral curve would result in the column in the regions of adaptation as shown in Diagram 4 B. (As a matter of fact the two methods are the same, only here instead of equilibrating the thorax to the head and pelvis, he simply reverses the process.)

There is another way of getting the pelvis into a horizontal position following the phase represented in Diagram 4 A, namely, by twisting the pelvis by the adaptation at the dorso-lumbar intersection, thus twisting the lumbar vertebræ with it. (Diagram 4 C.) Then we would have as a result that the lumbar vertebræ

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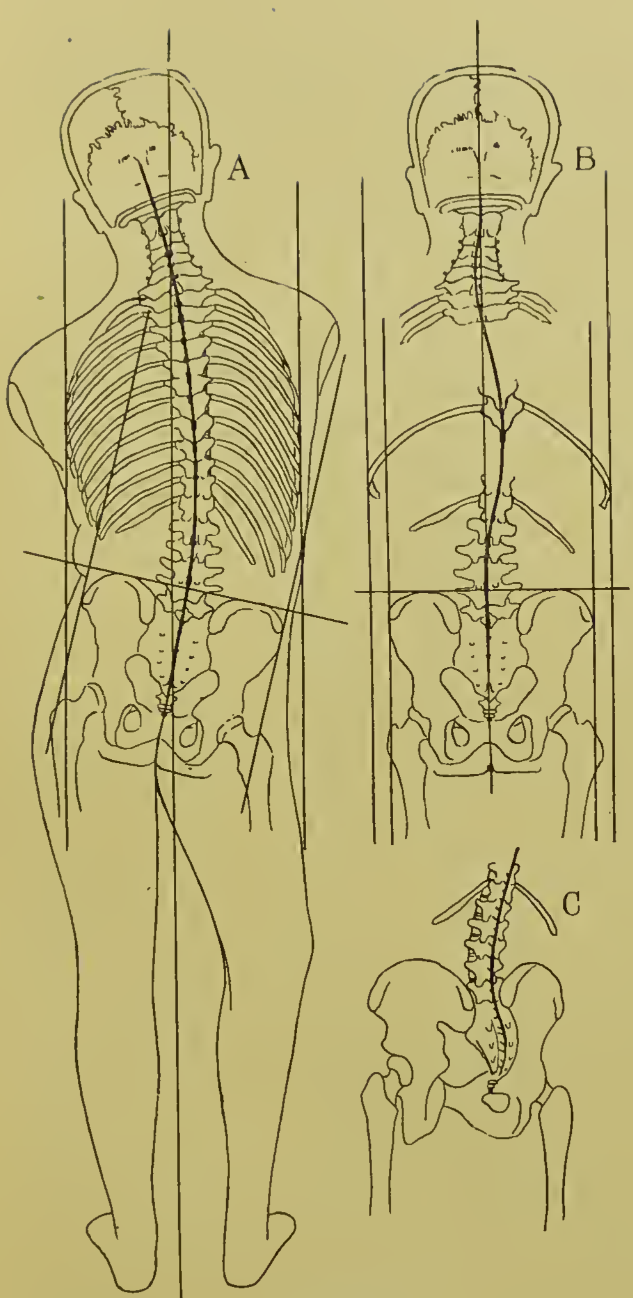
are gravitation lines drawn as lateral tangents to the chest walls and indicate the unequal distribution of the weight of the thorax with reference to the pelvis. Dotted line on the right indicates the contour which the thorax must approximate, to gain the easiest balance. Result in the spine must be either total bend or compound bend as indicated by either of the curves on the right.



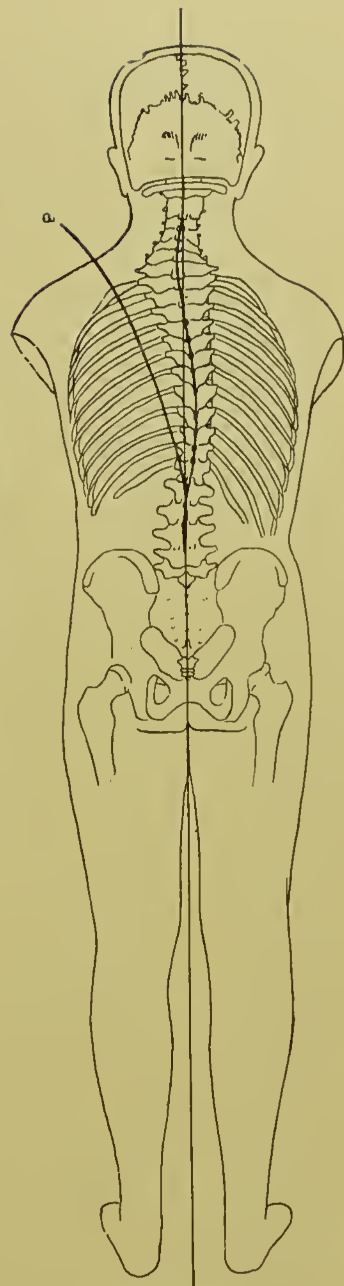


Diagram 4. Diagram 5.

Diagram 4 A. Recovery from 2, where head, chest, and pelvis recover as one piece, accomplished by bending the knee. Rib distortion maintained. The line of the spinous processes is identical with that in Diagram 2.

Diagram 4 B. Further recovery from 4 A (or follows 2 directly). Head and pelvis leveled and equilibrated to thorax as shown by tangential lines. Result, a compound curve in spine.

Diagram 4 C. Similar recovery from 3, the pelvis here being leveled without the bend in the dorso-lumbar spine, namely, by a twist.

would point to the left and the spinous processes to the right, and in the final position we would get one right total curve of the spinous processes beginning with the sacrum.

Diagram 5 represents the ultimate and typical recovery from the deformation of Diagram 2 after it has passed through the intermediate stages, such as indicated in the intermediate diagrams. The curve ending at (a) indicates the original curve of the spinous processes in its deformation bend, not in its exact location in space, but simply as relative to the lumbar spine. By reproducing this curve of deformation in this diagram of ultimate recovery, we may note that the point of adaptation is in the dorso-lumbar intersection, and if our assumptions so far are reasonable it will be apparent that the thorax, having moved as a segment at the dorso-lumbar intersection to gain its deformation position, and having accordingly met with distortion in the ribs, has then recovered by adaptation of the same flexible dorso-lumbar intersection; but that the approximation of the lateral rib wall to the column being maintained, the unity of the dorsal column has been broken up in order to adjust the thorax to a new balance.

We have so far pictured the spinal curve as being formed as a result of equilibration during recovery. Let us next represent the curve as a result of deformation direct. Let us, therefore, assume a bend carried out so prolongedly or so repeatedly that the column itself has been strained beyond the elastic limit and a permanent distortion arrived at. Then the convexity of the bend in itself become, a factor in the approximation of the column to the lateral wall (Diagram 6). Recovery from this position may take place with or without dorso-lumbar adaptation. If the elements of the whole column become fixed in their relationship it will be without dorso-lumbar adaptation and imply a total curve after recovery. If only the elements of the dorsal column become fixed in their

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Diagram 5. Recovery from 2 with the intermediate stages left out. The line ending at (a) indicates the original direction of the deformation of the spinous processes. This branches from the present line of spinous processes at the dorso-lumbar region, thus indicating the region of greatest adaptability for deformation and recovery. From the simplest point of view, the approximation of the lateral rib wall to the column, due to deformation, is now maintained at the expense of compensatory curves.

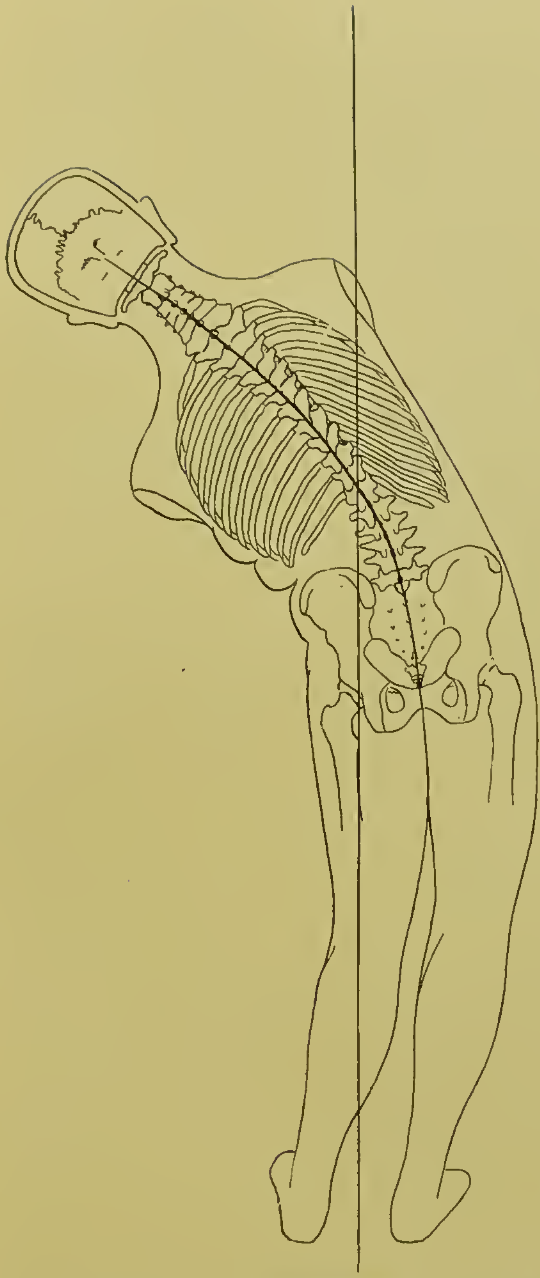


DIAGRAM 6.

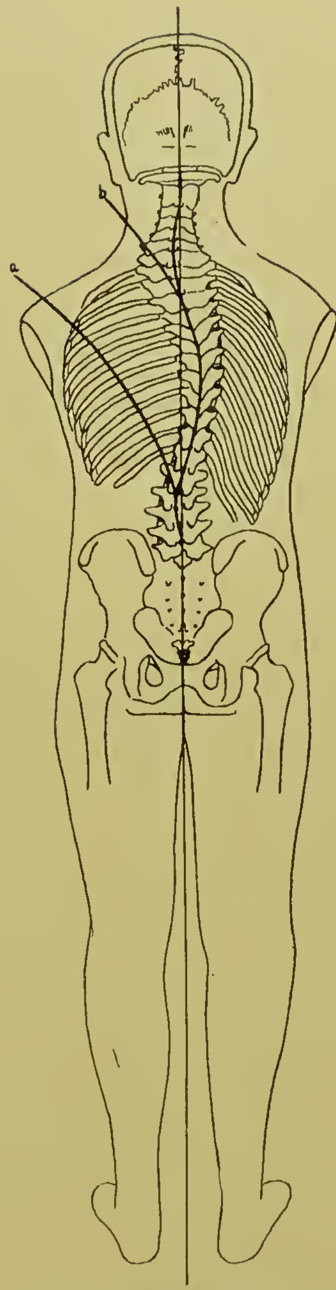


DIAGRAM 7.

DIAGRAM 6. Deformation. In this diagram besides the rib distortion, we assume an actual permanent bend in the dorsal spine, thus the convexity of the bend in itself becoming a factor in the approximation of the column to the lateral wall.

DIAGRAM 7. Recovery from 6, the bend of the dorsal spine being retained. The line ending at (a) indicates the original bend of 6 in the line of spinous processes. The line ending at (b) is the same after recovery but before the head is equilibrated. The two lines meeting join the present line of the spinous processes at the dorso-lumbar segment again showing where the greatest adaptability is. The equilibration of the head forms the curve in the cervical region.

relationship it will mean a compound curve. This is more likely as the dorso-lumbar intersection is one of such adaptability, as we have often pointed out. Further than that, if we merely assume that the ribs preserve their deformation, then this deformation must still further enforce the deformation of shape of that part of the column to which the ribs are attached, namely, the dorsal part. So, if in the process of deformation a bend takes place in the column and the ribs become deformed, then if they take a permanent set is is easy to conceive how this permanent set in the ribs must hold the dorsal column in a new but fixed relationship, so that after recovery this relationship must be permanently retained. In Diagram 7 the curve ending at (a) indicates the original direction of the curve of the spinous processes during deformation, which, compared with the ultimate curve, demonstrates quite graphically how recovery may take place by means of dorso-lumbar adaptation. The curve ending at (b) is the line of recovery before the head is equilibrated. After this equilibration another curve must take place in the cervical region as shown.

Deformation from Twist.

Deformation from twisted positions is an easier problem. We might conceive twist as taking place from the floor or from the pelvis. Diagram 8 represents a twist beginning from the floor. If this position is taken prolongedly or often, the dorsal column will once more show its weakness after the manner demonstrated in the previous papers, and the bodies will tend to retrograde so that they front towards the side of the thorax which is becoming narrower. (Diagram 9 A.) Then on recovery we may assume a partial preservation of that deformity so that one side of the chest will be narrower than the other and a comfortable balance can only be obtained by shifting the thorax to a place where the weight is more equally distributed, implying either a compound or total curve in the column. (Diagram 9 B.)

If the twist, instead of taking place from the feet, takes place from the pelvis (Diagram 10) it will mean a rotation of the dorsal column at the adaptable dorso-lumbar intersection, and the dorsal region with the ribs attached will rotate as one piece until its elements

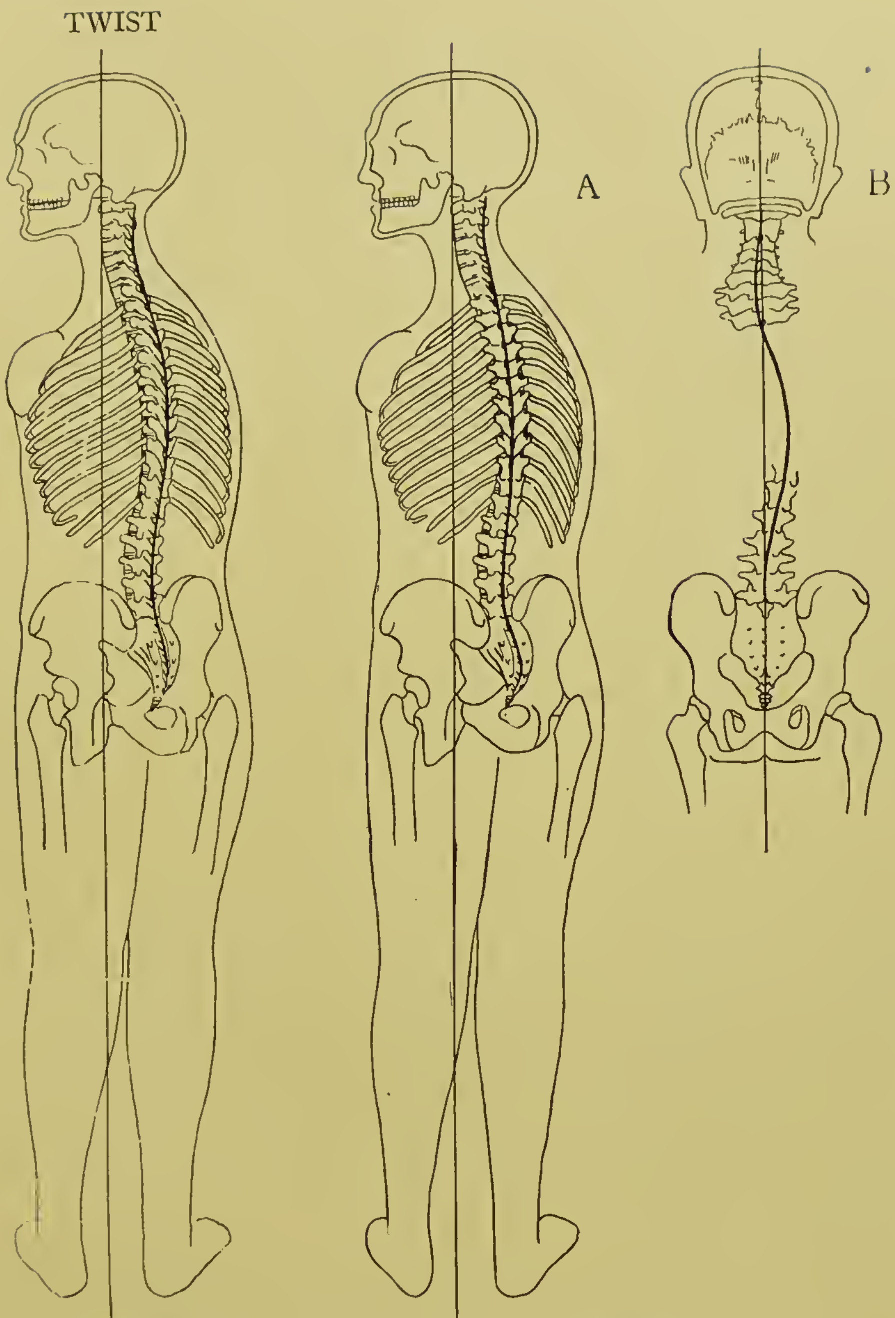


Diagram 8. Diagram 9.

Diagram 8. Deformation. Twist of whole body from the feet.

Diagram 9 A. Deformation continued from 8. Vertebral retrogression and rib distortion. Dorsal bodies are twisted with respect to the lumbar. Approximation of lateral rib wall to the column.

Diagram 9 B. Recovery from 9 A with chest deformity partly maintained. This means an untwisting of the head and of the pelvis with respect to the dorsal region implying a dorsal curve.

react according to the laws of the tendencies. Here we get as a direct result of the deformation process a right dorsal curve; for if the dorsal column rotates, its dorsal convexity must become a lateral convexity and we have the final position of the scoliotic at once, except of course for the retrogression of the vertebræ and the recovery of the head. When the vertebræ finally retrograde (Diagram 11) they will do so in their new positions and thus fix the lateral curve permanently. Head recovery must imply again an additional cervical curve. Diagram 12 represents a comparison of the lines of spinous processes in a deformation and recovery position. The curve ending at (a) being the deformation curve, once more demonstrates how we can point to the dorso-lumbar intersection as being the region of adaptability.

So we have detailed various formulæ by which the lateral curve in the column may develop, but in unfolding these plans separately, we assume that the forces implied in different ones may act co-ordinately, and from the broadest point of view many of the processes are either one, or closely allied.

Wedging of Vertebral Bodies.

Leaving the subject of the lateral curve we next return to the change in shape of the individual vertebræ. We have already pointed to the deformation of the arches. We now point to the bodies themselves. We find the bodies wedged in the region of maximum curves, that is, in the middorsal region, and where the curves change most abruptly in the lumbar region. Thus in a total curve of the column the wedged body is near the sacrum and in a compound curve we find the wedged body in the mid-lumbar region. (Fig. 3.)

These manifestations are again structural adaptations to the forces brought to bear, the substance of the individual bodies equilibrating itself to the stress in the path of diminished resistance. Consequently if a permanent bend takes place in the column according to any of the formulæ enumerated above, then we have a right to look for actual change of shape in individual elements of the column. Therefore, we may say that wedging in the dorsal column takes place to adapt itself directly to the new

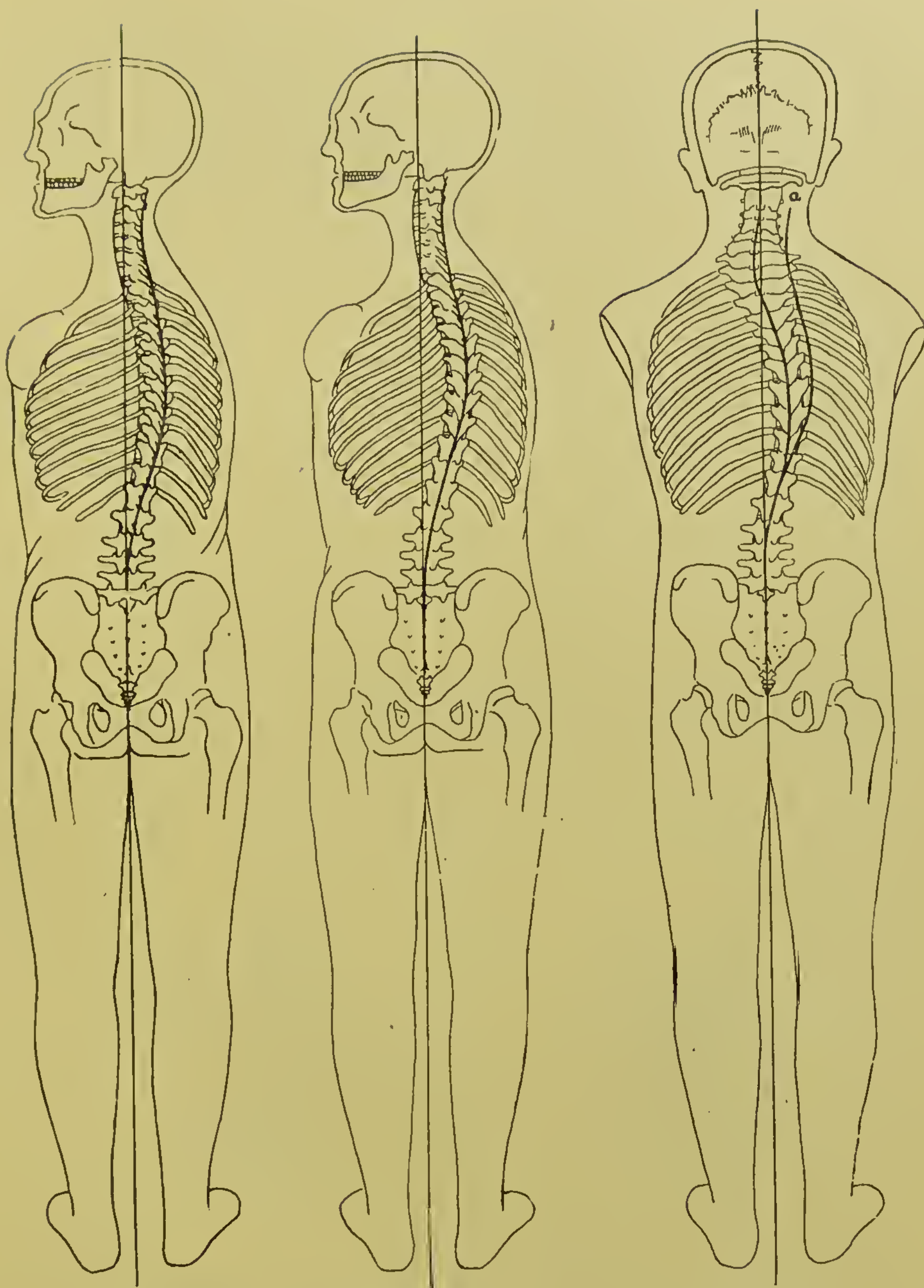


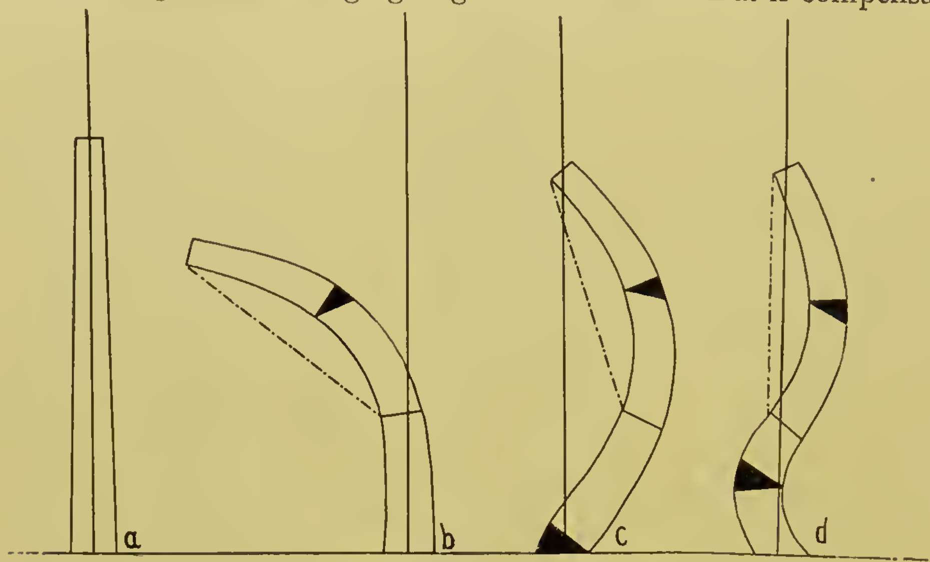
DIAGRAM 10. DIAGRAM 11. DIAGRAM 12.

DIAGRAM 10. · Deformation. Twist from pelvis.

DIAGRAM 11. Deformation of 10 continued, in which retrogression of the vertebræ has taken place.

DIAGRAM 12. Recovery from 11. The line ending at (a) indicates the direction of the spinous processes during deformation, branching from the present line of spinous processes at the dorso-lumbar section as with lateral bend, here again the region of greatest adaptability. Once more approximation of column and lateral rib wall is maintained.

conditions of bend in that region. If now we picture the column as recovering as a total curve and the pelvis held horizontally, there must be an additional conformation of substance in the lowest lumbar region and wedging might result there. But if compensa-



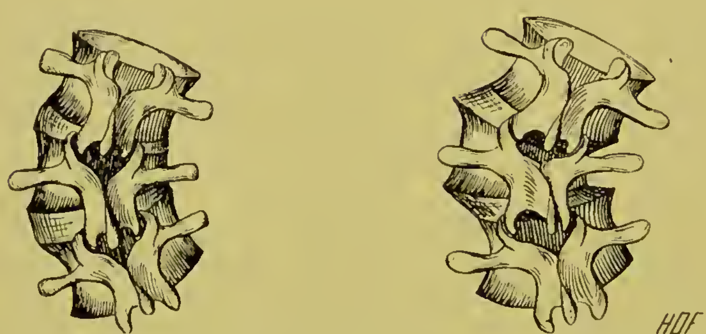


PLATE 2. Upper diagrams show the manner of wedging of the dorsal and lumbar columns following bend. (a) Column straight. (b) Bend. As a result of strain an actual change of shape implying a wedge in dorsal region. (c) Recovery. Dorsal arc retained. Great strain in lowest lumbar region implying wedge. (d) Recovery with compensation. Wedging in mid-lumbar region.

Lower figures show how a wedge formed in the lumbar region must imply a sliding out of the wedged body from between the two enclosing bodies, thus dragging the bodies of these enclosing vertebræ with it, while the arches are linked together. This is one way in which a twist of the lumbar vertebræ takes place.

tion took place in the usual region, the middle lumbar vertebræ would come under strain until they became wedged in the necessary direction. So the change of shape of the bodies may be regarded as due partly to conditions of deformation direct, and partly due to ultimate conditions of balance. We have tried to represent these points in the upper figures of Plate 2.

If we remember that twists and lateral bends result in approximately equal distortion for the thorax and consequently that the compensation which follows in the lumbar region must be the same, we might find wedging occurring in an exactly similar way following original twists.

Permanent Twist of Lumbar Vertebræ.

Finally we must say a few words as to the permanent twist of the lumbar vertebræ which often occurs. There are three ways of explaining this lumbar twist. In the first place it may occur after the fashion already explained as a result of leveling the pelvis, as shown in Diagram 4 C; second, it might be the remains of a primary twist of the whole spine where the thorax alone had recovered, and finally, it may occur as a result of wedging in the lumbar region. Thus, if you take any wedged block and squeeze it between two enclosing blocks it will tend to slide out from between the two, being driven in the direction of its base. In the case of the vertebræ, the wedged body will tend to slide out in the same way, but being connected with the enclosing bodies by means of intervertebral discs, it will tend to drag these enclosing bodies with it, and this of course must mean that these enclosing bodies twist with respect to the positions of their interlocking arches. This point is brought out in the lower figures of Plate 2.

Concluding Remarks.

Before closing, let us briefly run over some of these points. We started out with the assumption that in certain postures the bones tend to deform without actually doing so, and that if that force implied by taking these postures is carried on long enough or repeatedly enough, something must give, and that the giving must take place according to the tendencies figured out before. In other words, having studied tendencies or strains in terms of

distortion we believed that we had a right to predict that the force which is behind these tendencies might explain actual distortions if the resistance which prevents actual change of shape loses its ratio with respect to the force brought to bear.

On these assumptions alone we were able to explain many of the final deformities as they are actually found in the pathologic specimen. Others, however, could not be explained so directly, being due, we believed, not to the stress of deformation itself but to the laws of adaptation where the total body structure, after having acquired the original derangements of deformation, had to re-equilibrate itself in its erect attitude according to the requirements of gravity. In this way we showed how, after each recovery, the total balance became restored but with a slightly added change in symmetry.

In the thorax we started out with the assumption that the dorsal spine was an integral part of the thorax and that it moved with it as such, but we have now demonstrated how the vertebræ, making up the dorsal column, retrograded, and how even while retrograding these vertebræ furthur lost their original relation to each other as well as their individual shapes, on account of the developing lateral bend, which means that the dorsal column has not acted as an integral part of the thorax after all, thereby seeming to contradict our original assumption. But that is where the pathologic comes in, and the disintegration of the dorsal column is a manifestation of the breaking up of the unity of the thorax, expressing graphically the direction of the weaknesses which were already indicated in describing the normal tendencies. On the other hand, even if this unity is being destroyed a new unity is being built up; even as the thorax is breaking up during deformation it is all the time being put together anew with respect to ultimate conditions implied in erect attitudes, so that in the broadest sense the deformed thorax is still a unity and must still tend to adapt itself as such to the other parts of the body. From this point of view we see a most important manifestation of that principle which is the basis of all these conceptions, namely, that the structure equilibrates itself, not only according to the vicious forces directly, but also to re-adapt itself to other parts according to the derangements so acquired.

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7 # 3

The Mechanics of Lateral Curvature.

Fourth Paper: Significance and Explanation of Certain Clinical Signs.

Fifth (Final) Paper: Elaborations and General Abstractions.

BY

HENRY O. FEISS,

Cleveland, O.

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THE MECHANICS OF LATERAL CURVATURE.

Fourth Paper: Significance and Explanation of Certain Clinical Signs.

HENRY O. FEISS, CLEVELAND, O.

In the preceding paper we attempted to build a hypothesis based primarily upon the laws of normal tendencies, and attempted to show how positions of lateral bend or twist might culminate in some such distortions as are found in the scoliotic specimen.

The conclusion as based upon the hypothesis was that the final condition in the scoliotic represented the result of two distinct processes, first, the process of deformation, in which the peripheral stresses brought about certain distortions directly, and second, the process of recovery, in which the distortions produced by deformation and persisting as residual effects, occasioned permanent readjustments of parts, in order to make those parts conform with ultimate conditions of erect balance.

Hand in hand with the evolvement of this theory, we presented as evidence in its favor the various distortions of the pathologic skeleton, showing how most of them could be explained according to such reasoning.

The aim of this paper is to examine the living subject in order to ascertain if the clinical signs cast any new light upon the subject. At the start, we will concern ourselves with two propositions: first to show that there is a relationship in the living between the normal and the scoliotic, and second to show that such a relationship, if discovered, bears out deductions based on the laws of normal tendencies as arrived at in the previous paper.

In this way we hope to confirm by analysis that which we con-

structed by synthesis. We must, of course, make our analytic deductions without reference to, or prejudice in favor of, any deductions previously made. If deductions thus made from new premises correspond to earlier ones made in an altogether different manner, then will our reasoning seem to rest on a firm basis.

What is the relationship between a normal individual and a scoliotic as we see them in the living? Comparing two such individuals we note in the scoliotic a number of variations from the normal. If we are called upon to select the pertinent phrase which best describes any or all of these variations, the name of but one quality is sufficiently broad to convey our meaning. The name of this quality is asymmetry. This asymmetry, or the inequality of lateral homologies tells us emphatically which is the abnormal.

If we are to make further inquiry as to the nature of the asymmetry in the patient, the reasonable course to pursue is to diminish the difference between the two and to study the steps by which this difference is diminished. If we attempt to approximate the two by this method, it will be expedient to have in mind an intermediate basis either real or imaginary, which is more closely allied to each extreme (regarding the normal and the abnormal as the two extremes) than the two extremes are allied to each other. Let us seek for such an intermediate basis.

If we take a typical case of scoliosis with the usual right dorsal curve and the accompanying rib deformation (Case I, Fig. 1) and place that patient next to a normal individual (Fig. 2) we see no intermediate basis for comparing them as they stand before us. We only see that the normal is symmetrical and the abnormal asymmetrical. That we are unable to symmetrize the abnormal goes without saying, so our first step must be to make the normal asymmetrical. There is but one thing to do, that is to divert the pose. Now simply diverting the pose in the normal, even if it brings about asymmetry, does not in itself draw the two individuals closer. Let us, therefore, also divert the pose of the abnormal. This again if done without calculation, does not in itself suggest any relationship between the two, so instead of

simply diverting them at random let us divert them into parallel poses and see if they cannot be made to resemble each other by that method. We can have both individuals move from the hips into various directions and always keep parallel to each other.

FIG. 1. Case I scoliotic erect (recovery).

FIG. 2. Normal erect (recovery).

FIG. 3. Case I scoliotic side bend (pure deformation).

FIG. 4. Normal side bend.

The result is distinctly significant, for by manipulating the two in this fashion, we finally are able to obtain a position in which they bear a striking resemblance to each other (Figs. 3 and 4). In the particular case under observation this position of resemblance is a lateral bend to the left, and we note as an important fact that the patient takes that position quite naturally and

easily, whereas in attempting various other positions no such free motion is manifest. We have then isolated a position of diminished resistance in which the patient strikingly resembles the normal. It is in this fashion that we diminish the difference between the two and obtain a basis for comparison.

Having shown the method for finding such a basis, let us see what has happened in order to suggest the resemblance which links them together. The chief attribute of resemblance in the two is the adjustment of contours—thus we note that the contours of the chest adapt themselves in each individual to the contours of the pelvis and thigh so as to form practically similar curves. We also see that in each case the soft strata are stretched over the bones on the convex side in the same tense fashion, while on the other side we note signs of relaxation with beginning folds at the waistline. In the spinal column, we note that the lines of spinous processes in the two cases form complete curves, for the scoliotic curve which was originally compound is now rendered simple by the obliteration of the cervical and lumbar arcs. So it seems that both individuals are under similar strain. In no other position can such points of resemblance be demonstrated, and we feel certain that any observer after taking a look at the patient in this position must be struck by that resemblance, so that, in at least this case, we can definitely state that there is a relationship in the living between the normal and the scoliotic, thus disposing of our first proposition.

Let us proceed now to the second proposition, to show whether such a relationship bears out deductions based on normal tendencies as developed in our hypothesis in the previous paper. If we keep that hypothesis before us we cannot fail to recall that it was from just such a position in the normal that we attempted to construct scoliosis. It was by posing a normal individual in a side bend that we could show the stresses and strains which offered at least one way (not alluding to twist for the present) which could explain the skeletal deformities of scoliosis. In that previous paper we styled such a position as one of deformation, so the immediate inference is perfectly simple: namely, that the living scoliotic can be reduced to an intermediate position

resembling the normal, which position in the normal was one of deformation in the synthetic theory, and our second proposition is disposed of.

There is now a corollary depending on the second proposition as follows: If this reduced position is one of real deformation then we ought to see graphically expressed therein the results of strain of deformation pictured as isolated from the changes consequent on recovery (see the second paragraph of this paper). In other words, the differences between the abnormal and the normal in such a position must be those very effects which ought to follow deformation as deduced from laws of normal tendencies—so we look for attributes of difference.

We note first of all the contraction of the thorax on the convex side, denoting thereby the approximation of the spinal curve to the lateral rib wall. We also note the increased sharpening in the curve of spinous processes, and finally if we examined the case closer we could make out the angulation of the ribs and the retrogression of the vertebræ. These are the very things which have been explained in our previous paper as resulting directly from stress of deformation, and our corollary will seem sound.

Besides these differences, however, there is another not pointed out in the previous paper (as it is only clinically apparent). We refer to the diminished resistance in bending in a certain direction. The very fact that there is a direction of diminished resistance must in itself suggest the history of previous strains in that direction. (These marks of strain are now demonstrated, being just those things we referred to as points of difference.) Regard the normal again, note where the thorax is under greatest tension (peripheral), note the bending strain in the column (central) and we ask ourselves whether this normal, if strained as we see him through a long period can avoid gaining just such marks of strain as we see in the abnormal. These points of difference represent, then, not different kinds of stress, but simply different degrees of stress, and the very nature of the difference is an important argument in favor of their fundamental resemblance.

In a word, then, the distortions of the scoliotic seen in such a position seem to be nothing more nor less than those which

ought mechanically to follow a similar pose in the normal; therefore, as we have a picture of the effect of deforming stresses practically isolated from such effects as are implied in the recovery, we may refer to that position as one of pure deformation.

To continue this line of observation, let the two individuals recover, the normal and the abnormal (see again Figs. 1 and 2). Let them both take their erect attitudes, thus bringing into play the forces implied in ordinary functional balance, and immediately the adaptation of the segmented parts of the body to present conditions of balance becomes apparent. Both have readjusted the segments so that they are balanced around the line of support, both have replaced their heads to be about central over that line (at the same time leveling their eyes) and both have retained the thoracic shape seen in the intermediate position.

But in the one the parts have regained symmetry and in the other they have not. In the one, the line of spinous processes comes back to straight, in the other there develop cervical and lumbar curves. In the one the contours of the chest have composed themselves properly and harmoniously on each side to other contours, and in the other there is a distinct absence of composition and harmony. Here, then, is the key-note for understanding the great difference between the two:—it is simply that the asymmetrized parts in the abnormal require a new balance; thus the chief distortion gained in deformation, namely, that of the thorax, has been permanently retained and this deformed segment, having lost its shape and symmetry, must now (irrespective of its acquired distortions) balance itself anew to the rest of the body. Hence we see changes of lateral contours, lack of composition and harmony, and newly developed lumbar and cervical curves, and only so because these things have to take place in order that the newly shaped thorax may adapt itself to ordinary functional requirements.

If, therefore, we conceive that the distortions of the thorax alone result from stresses of deformation, and that these distortions become fixed, then scoliosis is pictured in the recovery without any further assumption. It is from this point of view

that we may best appreciate the importance of such distortions, for even without knowing the mechanics of the changes as conjectured from the laws of normal tendencies, we may note from the clinical signs alone, that it is the deformation of the thorax which marks the difference between the scoliotic and the normal. Regard the thorax as a segregate of the body, picture its defor-

Fig 5. Case II erect.

Fig. 6. Case II left bend (pure deformation).

mation as you see it before you in the scoliotic, interchange in the normal the transformed thorax for the good one, and you have scoliosis.

Analysis of Other Cases.

Let us see how these points are borne out in other types of scoliosis. Case II (Figs. 5 and 6) is another case with a compound curve somewhat similar to Case I. The case brings out about the same points but demonstrates especially well the acuter sharpening of the spinal curve. Case III (Figs. 7, 8 and 9) is interesting as being a case of similar type and showing quite well the difference between right and left bend. The long sweep of the body and the further degree of motion to the left demonstrates quite graphically that this is the direction of diminished resistance. Moreover, the formation of the total curve of the spinous processes in that direction as compared with the broken curve, when the body is in the opposite direction, must suggest the nature of previous strains.

Taking a case of simple total bend to the left (Case IV, Fig. 10) and a position of pure deformation is very easily discovered. For such a case that position is apparently a bend to the right. If we carry out such a bend (Fig. 11) we note that the patient takes it naturally and easily as though it were one habitually

Fig. 7. Case III erect.

Fig. 8. Case III left bend (pure deformation).

Fig. 9. Case III right bend.

assumed, and if we bend a normal individual (Fig. 12) next to him in a similar direction, it is difficult to distinguish the normal from the abnormal if we did not happen to know in advance which was which. Such a position is clearly one of diminished resistance and carries with it none of the changes consequent on ultimate conditions of erect balance, for in it are revealed the stresses of deformation and deformation alone.

If a patient with scoliosis can be reduced back to an intermediate position, then, according to the laws of normal tendencies, some of these cases might show diminished resistance in a position of twist.

FIG. 10. Case IV erect.

FIG. 11. Case IV right bend (pure deformation).

FIG. 12. Normal right bend.

We must remember, however, that according to our hypothesis there is this difference between lateral bend and twist, namely, that the twist being a deformation position causes deformation in the erect attitude without requiring much recovery, except

for the head. So looking at a scoliotic and conceiving him as possibly derived from twist, we see him practically in a deformation position, with the head recovered, without any further experimental posing. So the position of pure deformation for cases derived from twist would in itself be almost a final position of scoliosis. We should, however, expect that certain cases might be reduced to a deformation position of twist, in which the strains of deformation are graphically revealed even as in cases derived from lateral bend. Selecting a certain case (Case V, Fig. 13), and twisting her as suggested by the scoliotic distortions, we may note just such a condition (Fig. 14). The scoliotic dorsal curve becomes intensified and the peripheral tension of the soft parts seems to bear spirally on the thoracic parietes, apparently tending to bring about the very distortions which are present. Place a normal in a similar position (Fig. 15) and we note the correspondence of the two, the distortions which are only suggested in the normal being carried out as facts in the abnormal.

Although we have regarded cases of scoliosis clinically as apparently derived from two kinds of deformation, we feel that these two, lateral bends or twists, can very seldom occur isolatedly, the two are probably almost always combined and the forces implied in each must act coordinately. So in the material at our command we have found that we have been able to gain a position which resembles the normal most strikingly by adding lateral bend to twist or the reverse. Thus in the four cases used to illustrate lateral bend, a slight twist has been necessary to show the best position of pure deformation. Even in Case V selected for pure twist, a purer deformation picture would have been suggested by adding lateral bend. Not alone this, but we have also found that a slight forward bend may still further emphasize the resemblance of the scoliotic to the normal. At any rate, we may take practically any scoliotic and if we pose him intelligently and carefully, we may almost always be able to obtain a suggestive posture in which we can read the path of deformation from the normal. In a few, the path is most intelligible by regarding the scoliotic as he stands before us and simply twisting the head,

in others by placing him in a position of lateral bend, in others, again, by adding a forward bend, and in most, by combining all three. How to interpret the patient must depend upon our judgment as well as our experience. We need only bear in

FIG. 13. Case V erect.

FIG. 14. Case V twist (pure deformation.)

FIG. 15. Normal twist.

mind that the resultant distortion of either lateral bend or twist or both together, ought, according to previous deductions, to be very similar, for it is the final state of equilibrium gained by separate paths in separate cases, but in which forces are just the same in effect, even if different in direction.

The Position of Pure Deformation.

Let us then state in concise form what we mean by the position of pure deformation. It is that position which the scoliotic finds more readily than any other, and is obtained by experimentally posing the patient until a position is found in which he resembles the normal most strikingly. The importance of the position is that in it we may note as isolated, the representation of the effect of deformation stresses, manifested chiefly by the misshapen thorax and the peculiar adjustment of contours. It is a position of diminished resistance thus in itself indicating the history of previous strains, and being a position of diminished resistance and one that resembles the normal so strikingly, it affords a means of confirming by clinical signs, the deductions which we made conditionally from the laws of normal tendencies.

The position has another significance, for being the position of pure deformation it may be used to measure the amount of deformity. From this point of view it corresponds to what is styled in other joints as the position of permanent deformity. Thus to measure the permanent deformity of a joint we arrange the body so that adjacent joints take a certain standard relationship to each other at the expense of any fixed deformity in the joint in question. This may be done by eliminating that distortion due to compensation. For example, to measure permanent flexion at the hip we have to adjust the pelvis to the trunk until the lumbar column is straight and the resultant flexion in the hip, as then apparent, we speak of as the permanent flexion. In the same way in the scoliotic, we may measure the permanent flexion or what we have styled the pure deformation quite easily by adjusting the pelvis to the lumbar spine according to normal standards and then estimating the resultant deformity. In Case VI (Figs. 16 and 17) if we do away with lumbar compensation, we note a striking example of pure deformation, and we also note that scoliosis as pictured here is something more than a mere curve in the spinal column, it being, forsooth, a bend in the thorax finally adjusted to suit the requirements of erect balance.

In this connection we wish to refer to an interesting case which

recently came under our notice, because it demonstrates remarkably well the practical value of our point of view. The case was that of a man who had fractured his leg many years since and which had developed into such a shape as shown in Fig. 18.

FIG. 16. Case VI severe scoliotic erect (recovery).

FIG. 17. Case VI position of pure deformation.

FIG. 18.

FIG. 19.

FIG. 18. Author's case of severely deformed lower leg (following fracture) in position of function.

FIG. 19. Same limb in position of pure deformation. Note that the line of actual deformation of tibia is about the same, the difference between the two being simply in the compensation. (Compare with Case VI.)

The aspect of the leg as thus shown is the one in which it was being used and to us was very confusing until, by experimental manipulation, we obtained such a position as shown in Fig. 19. It was now at once evident that the deformity lay in the lower part of the tibia, the rest of the deformity being that of compen-

sation in the ankle to provide for function. So the position which revealed the history was the one we style pure deformation. (Compare with Case VI.)

Theory and Fact.

Having demonstrated these positions the question which is now before us is, do we ordinarily see such postures in the living as demonstrated in constructing this theory? Do we see individuals taking such positions as the position of pure deformation? The answer is no—or if we do, it is only in rare glimpses. Even in cases apparently following prolonged occupation, the faulty position that we see is not the position of pure deformation, because compensation is always in a measure concomitant. What we see is the end result of deformation plus recovery at a given moment (although the stresses of either one might be more active than the other at the time). In strictest theory we have to do with an unseen impulse symbolized in posture, but not necessarily carried out as such. Thus, whatever the cause or environment for postural diversion, whether it be occupation, congenital malformation in the skeleton, faulty weight-bearing, infantile paralysis, weakness, and whatnot, we assume that an impulse for diversion (and consequently for asymmetrical peripheral stresses) is conveyed from the nerve centers to rearrange the segmental parts and that almost immediately with the deformation stress there comes a reaction to equilibrate against such stress. From this point of view we have deformation and recovery taking place so close together that they are almost synchronous. Our earlier diagrams (in previous synthesis) are therefore only symbolic and our positions of pure deformation are for the most part artificial. Such pictures and attitudes of deformation represent the result, not of one postural diversion, but the totals of all, and our recovery represents the sum total of all recoveries, it being the end stage, or the position of final balance. This is the difficult point to make clear, but it is the most important point of the whole consideration. It means that all these processes are carried out together, first a cause implying an impulse for deformation; next an adaptation of structure to

the stresses following the impulse or following the diversion due to the impulse, and finally compensation in other parts for the structural changes—all taking place at the same time. What we have done is simply to have analyzed these elements separately. Thus if we designate the effect of one deformation as (a) and the effect of one compensation in recovery as (b), then the effect of the two is (a) plus (b). Now the effect of two deformations is 2 (a) and the effect of two compensatory changes during recovery is 2 (b). The total effect is 2 (a) plus 2 (b). So if we multiply (a) by any number of deformations as x and do the same with (b), we see that the final position represents x(a) plus x(b), and when we describe deformation we describe not (a) because that is infinitesimally small, but we describe x(a), x(a) being the result of a great number of strains pictured as isolated and added together. The same holds for x(b). Consequently when we speak of a deformation it is the position following all deformation impulses with the recoveries left out and it is one which is, in the main, artificial (because recovery goes hand in hand) unless we experimentally place our scoliotic in some such position when that is possible. We must always bear in mind that we are dealing primarily with the formulæ of stress, expressed by posture, to be sure, but not necessarily carried out that way. Thus we may conceive untold numbers of faulty strains with recovery going hand in hand, without the realization of an actual postural diversion. If we grasp this distinction between deformation stresses and deformation attitudes, we may be able to explain many clinical pictures otherwise abstruse.

Mean Equilibrium: (*Average Functional Balance*).

The ultimate condition of scoliosis is, as we have pointed out, not a condition due to deformation stresses regarded by themselves but is due to the deformation so produced plus the consequent changes of reequilibration according to ultimate conditions of balance. The condition is expressed best if we regard it as a state of mean equilibrium. That is to say, in the ultimate condition of scoliosis we simply have a state of average equilibration, having a posture in which the deformations and their recoveries

are commingled together in order that the individual may functionate in the usual manner of human beings (i. e., in the erect attitude). It is true that in the normal, asymmetry is the rule for proper function, but if we average all the asymmetrical positions together and the forces implied, then the average state will be equilibration with symmetry, while in the scoliotic, the average is equilibration with asymmetry.

How Various Final States are Derived.

We will now consider why in the ultimate condition of scoliosis we find variations. In the first place everybody will concede that there is a fairly typical scoliosis, namely, the right dorsal left lumbar type with posterior right rib convexity. (The fact that one kind is more common than any other in itself suggests that the deformation mechanics is usually along a given path and not due to a haphazard mingling of stress and strains according to the circumstances of individual causes and cases.) It is with this typical kind that we have been chiefly concerned, yet we know that there are other types. How are these derived? The problem is simple from the point of view that we have adopted. It is merely a question of final equilibrium and if recovery from deformation takes place to conform with ultimate conditions of balance, such recovery may permit several combinations, depending upon which segments act together. Thus, if in the original deformation, the column adapts itself to a total bend, then recovery may take place as a total bend and this may remain the final state. If, however, recovery takes place from the dorso-lumbar intersection as a more adaptable point a compound bend results as a final state. We may look at some of the recoveries with total curves as simply preliminary to a final state in which compound curves take place.

Explanation of Certain Clinical Manifestations not yet Cleared Up.

The Prominent Hip.

That one hip is more prominent than the other goes without saying, but how do we explain that in some cases of similar type

one hip is more prominent and in others the other, and that this particular point does not seem to follow any prescribed rule? The reason for this is the variation in the amount of deformation in the thorax, for in some cases the inequality of weight might require but little shift on recovery (Case III), whereas in others the thorax would have to jut way beyond the pelvis in order that it be properly balanced around the line of support (Case V). Thus we might expect, and do more frequently find, that the left hip is more prominent than the right on account of the compensatory shifting of the thorax toward the right. It is perfectly conceivable, however, that if a thorax has been contracted on the right side and a great amount of retrogression of the vertebræ has taken place that the weight will be so increased on that side by the superabundance of bone that the thorax would tend to shift toward the left with a greater compensatory curve in the lumbar region, thus still maintaining a right dorsal left lumbar curve and yet bringing about the prominence of the right hip. This condition is to be demonstrated in some patients.

The High Shoulder.

The height of the shoulder depends upon the distribution of weight and does not necessarily follow deformation in the thorax directly. If a man carries a weight in his right arm he will throw up that shoulder. In the same way with the scoliotic. The patient raises the shoulder to compensate for inequality of weight, and we might reasonably expect that either shoulder would be higher, depending upon the balance of that particular case.

Tipping of the Pelvis.

Just as with other specific details, we may find either side of the pelvis higher than the other, according to the conditions of the individual case. Thus, if during deformation the right side of the pelvis is drawn up on account of the peripheral strain, it is likely to stay up on recovery, but if on recovery a great amount of compensation is required in the lumbar spine, it may, on the other hand, be tipped in the opposite direction. Thus in Case III we find the pelvis apparently inclined upwards on the right,

whereas, in Case VI the pelvis is inclined just in the opposite direction.

Concave Torsion.

By concave torsion we mean the rotation of the bodies of the vertebræ towards the side of the concavity of the curve. It is observed only in rare instances, but is perfectly easy to explain according to previous formulæ. Let us conceive that the deformation takes place by a lateral bend and that retrogression of the vertebræ follows. Then let us say that the patient recovers according to the usual rule and that he takes his original position with only the vertebral retrogression maintained. Suppose in this position the balance has not been much changed from the original, then retrogression having taken place, the tips of the spinous processes might form a line convex toward the left while the bodies of the vertebræ might retain their original places. The difference between this and the usual condition is that in cases of concave torsion the thorax has not shifted and in the usual case the thorax shifts.

Classification.

From what has come before we now have an inkling of what the classification for these deformities ought to be if it is based upon the mechanical derivation. From the point of view expressed we can only conceive two kinds, rights and lefts. We cannot state definitely that a given case was derived from a lateral bend and that another case was derived from a twist because the two are combined in almost every case. We can only say that the posterior increased convexity of the ribs is on the one side or the other. We believe, then, that the basis for classification must be the deformation of the ribs for they express graphically the nature of the peripheral stresses which brought about the change. So the curve in the spinal column is only a secondary consideration. If we get a right thoracic contraction the other deformation must be such as would naturally follow in a prescribed path, or as compensatory effects depending upon the location of the other parts with reference to the deformed thorax.

Cervical curves, lumbar curves, high shoulders, prominent hips, and deformities of other kinds are simply to be regarded as compensatory changes in recovery and not as controlling factors in defining a type.

So in closing we once more lay stress upon the significance of the thorax. In dealing with the normal tendencies in the first two papers it was the thoracic walls that attracted our chief attention. Here we could demonstrate both superficially and by the use of Roentgen rays how the peripheral stresses had their initial effects upon the peripheral skeleton and how following these stresses in the ribs the diversion of the vertebræ seemed to follow as a secondary reaction. Then with these premises we were able in our third paper to explain many of the deformations of the scoliotic, and could explain practically all by adding to these initial deformations the compensatory changes due to conditions of ultimate balance. Finally, from the clinical point of view we have been able to reveal a position of pure deformation in which the thorax was the chief seat of change. Then in the final position of recovery we saw scoliosis, and that scoliosis pictured purely and simply by the adaptation of the deformed thorax to a body which may otherwise be apparently normal.

THE MECHANICS OF LATERAL CURVATURE.

Fifth (Final) Paper: Elaborations and General Abstractions.

HENRY O. FEISS, CLEVELAND, O.

Having in previous papers gathered anatomical evidence suggesting the relation between normal postural tendencies and the pathological findings in scoliosis (first and second papers), and having constructed a hypothesis in which the attempt was made to array our belief in logical (synthetic) form (third paper), we finally examined the living scoliotic and were able to show that many of the clinical signs were consistent with the explanation set forth (fourth paper).

The task before us must be, to point out the limitations of the work, to show how broader considerations not yet discussed adapt themselves to the hypothesis, and lastly, to examine the relationship of our effort to the works of other men.

Before undertaking these things a recapitulation will be in order. Briefly stated the theory stands somewhat as follows: There are certain conditions of normal posture which we assume to imply asymmetrical strains. Although we made no attempt to measure these strains accurately (mathematically) the forces and resistances could be analyzed and arrayed against each other. By so doing, tendencies could be figured out for the parts under strain which could best be studied in terms of distortion. In this way, we found that the peripheral stresses were of seemingly great significance implying tendencies (as read in terms of distortion) which were very suggestive of the ultimate distortions seen in the pathological skeleton. In order, however, to explain the pathological facts we had to assume that the strains

were greater than the resistance called forth in the structure as might be readily supposed on the grounds of prolongation or frequent repetition. Assuming this to be so, there had to be a change of form and substance to conform with the disproportion of strain to resistance which change continued till the structure became equilibrated to the force. This adjustment of the structure to the force (deformation) seemed to occur chiefly in a given part, namely, the thorax, so that following this, the body mass as a whole had to readapt itself to conditions of erect balance (recovery) which implied a second equilibration of the deformed part to the rest of the body, and this final adjustment was said to represent the state of lateral curvature.

In connection with this resumé, we must not fail to remind the reader of the distinction between the actual manner of distortion and its logical conception. The explanations as outlined in the third paper must not be looked upon as accurate accounts of malformations, but are to be regarded as formulæ of the forces bringing them about; otherwise, we would look for attitudes of deformation where we could not find them, we could not explain how the condition follows obscure or unknown causes, nor could we understand how phenomena which are most readily comprehensive, as successive in time, are practically synchronous.

Perhaps the safest and most practical notion is embraced in the idea already expressed (fourth paper) that in the ultimate condition of scoliosis we have to do with a state of average equilibration, that is a state in which the effects of deformation and their recoveries are commingled together, thus enabling the individual to functionate in the usual manner of human beings. We bore in mind that even in the normal, asymmetry is the rule for proper function, but if we average all the asymmetrical postures together and the forces implied, then the average state is equilibration with symmetry, whereas if we do the same with the scoliotic the average is equilibration with asymmetry.

It is also necessary to state that although we have emphasized the importance of peripheral stress, we do not mean that central

stress is to be omitted from the consideration. Perhaps we should have laid more weight on its significance in our earlier papers. Peripheral stress may be regarded as nothing more nor less than peripheral resistance, the primary force being that entailed in the primary diversion of the segment in the deforming posture. Theoretically, as the peripheral stress is coincident with the original diversion, it ought to be regarded as just as primary as the force of the diversion. However, if we regard the segmental movement as primary, and as the dorsal column moves as a necessary part of the thorax, some of that primary force may be regarded as central, that is as springing from the column itself. Whether that is true or not, such a central force in the isolated column could not in itself explain all the distortions of scoliosis. It might account for some as we assumed in our third paper, basing one formula (Diagram 6) on an initial primary deformation in the column; but to explain the remaining distortions the stress of peripheral resistance had to be considered, otherwise we would be at a loss to account for such effects as the contraction of the thorax, the retrogression of the vertebræ, the position of the sternum, etc. Peripheral resistance always implies primary force, central or total, and this original primary force always implies peripheral resistance; so that all the deformation distortions are to be explained by such actions and reactions reciprocally effective.

The Distinction Between the "Cause" and the "Mechanics."

The summary above given will serve to show how we have dealt with the subject concretely, but it is now expedient to view it from a more fundamental standpoint in order to make as clear and definite as possible the scope and limitation of the work.

Going back to the expression, "Laws of Tendencies," that term, it will be recognized, has been borrowed from Mill (System of Logic) who uses it to express the "Laws of the Causes." Figuring on a basis that there might be a relation between the normal and the abnormal and that this relation is suggested in stresses brought about by asymmetry in the normal, we deduced

that such stresses if carried too far in the normal might produce the abnormal. From this point of view, the stresses are dealt with as the possible causes of lateral curvature and when we refer to these as tendencies we believe we have conformed to Mill's idea. Now it has been shown by the same high authority that in explaining a law of nature, a real and logical advance can be made if we show how the effect follows the cause by detecting an intermediate link. He cites as a pertinent example that of a nerve and its sensation, as follows: "For example: mankind were aware that the act of touching an outward object caused a sensation. It was subsequently discovered, that after we have touched the object, and before we experience the sensation, some change takes place in a kind of thread called a nerve, which extends from our outward organs to the brain. Touching the object, therefore, is only the remote cause of our sensation: that is not the cause, properly speaking, but the cause of the cause—the real cause of the sensation is the change in the state of the nerve. . . . The sequence, therefore, of a sensation of touch on contact with an object is ascertained not to be an ultimate law; it is resolved, as the phrase is, into two other laws—the law that contact with an object produces an affection of the nerve, and the law that an affection of the nerve produces sensation." So in our work we must remember that there are remote causes as Mill expresses it, and that the sequence with which the effect follows the cause can be resolved into two laws, namely, the law by which the proximate cause follows the remote cause and the law by which the final effect follows the proximate cause. By the "Laws of the Tendencies" we refer to the laws of proximate causes and these laws are what we style the mechanics. The remote causes are the impulses primarily and necessarily assumed in order to make the proximate causes active. To be more explicit, and bearing in mind Mill's example of the nerve and its sensation, let us take as an example a case of infantile paralysis. We positively know that infantile paralysis may be an antecedent of lateral curvature. But, even if we know that this disease is the cause of the deformity, we can make no true scientific advance until we explain how it produces

that deformity by detecting an intermediate link. Thus, if we determine by research that certain stresses are apparently let loose by the disease of the cord, and that the distortions in the skeleton might possibly be due to those stresses, then we have the clue for detecting that intermediate link. These stresses, or what we style tendencies, are the ones which we have tried to isolate and which we have referred to as being perhaps the proximate causes of the condition. Thus in the example stated, we might determine that following the lesion of the cord the erector spinæ muscle is paralyzed, following which the trunk tends to collapse, and that this again is followed by unequal distribution of peripheral stress, due to which there develop certain distortions in the skeleton in accordance with the formulæ earlier set forth. By this means we might develop that intermediate link between the remote cause (viz.: the disease in the cord) and the ultimate effect. (Unfortunately, in the ordinary cases of scoliosis following infantile paralysis, the muscular changes are so complicated that we cannot draw sufficient deductions to establish our theory; but if we were able to calculate the exact amount of stress lost in each paralyzed muscle, we would be able to confirm or disprove our hypothesis by such means alone, thus at least demonstrating the rationality of the method.)

In the same way Boehm has recently shown that a great number of scoliotics present certain congenital anomalies in the skeleton. The work is of extreme value, but that value may be enhanced if the succession of phenomena is shown through which the actual skeletal distortions follow the anomaly—otherwise we cannot be said to understand the condition. Thus, following an anomaly in the column we might be able to prove that the balance is in some way disturbed; if then we are further able to show that there takes place an unequal distribution of peripheral stress and that the succeeding phenomena develop according to certain formulæ, we thus detect the intermediate link between the initial or known cause and the final effect.

Therefore, in looking for the laws of proximate causes and seeing the close relation between asymmetrical posture and the pathological condition, we feel perfectly justified in using that

close relationship as a possible basis for determining the invariable mechanical antecedents and deducing their formulæ. From this point of view the distinction between the cause and the mechanics should be very clear. In many cases, to be sure, the inciting cause cannot be traced but if we assume that there must have been one, and class that assumed cause with those remote causes (such as infantile paralysis and congenital anomalies) which can be demonstrated, then such a distinction between the cause and the mechanics will so simplify our work that we can really hope to make a scientific advance.

In order to avoid confusion, we should reserve the term "Cause" for those remote antecedents preliminary to the actually effective mechanical tendencies, and thus even if we have stated that the "Laws of the Tendencies" logically refers to the "Laws of the Causes" there will be no contradiction if we remember that distinction between such causes as are remote and such as are proximate. In order to indicate the distinction a little more practicably, we have prepared the following crude classification.

(1) **Remote causes** (either assumed or demonstrable):
   Prolonged asymmetry as may be due to occupation or to school,
   Weakness
   Congenital anomalies of skeleton,
   Infantile paralysis and other cord lesions,
   Diseases of the skeleton,
   Systemic disease,
   Short leg,
   Faulty weight-bearing (as implied in any of the above), etc.

(2) **Proximate causes** or invariable mechanical antecedents (mechanics):
   The stresses and reactions let loose by any of the remote causes.

How Weight-bearing Enters In.

We are now prepared to understand one part of the subject to which we have made no specific reference and yet which is so

closely interwoven with the consideration of the whole, that its omission would be a source of great weakness in defending our hypothesis. We refer to weight-bearing.

We stated originally, that in an erect attitude the weight of the superimposed parts must be balanced around the line of support. Therefore, weight must be recognized as an essential and primary factor as entailed in the very use of the term balance. (Thus, if one segment balances another segment superimposed, it must feel its weight as otherwise there would be nothing to balance.) Then when we state that on recovery following deformation the parts must readapt themselves for purposes of erect balance, and when we remember that the weight of these parts is the constant quality of substance necessitating such a balance, we can readily understand what part weight plays in the actual recovery.

Even if this is true, it does not show the full significance of weight-bearing and the question must come up as to how we are to regard its dynamic influence as a force or causative agency in the deformation proper. If we take an example of a cannon-ball launched [into space by a projectile force, we may state according to Mill (System of Logic), "That the original projectile force which set the body moving is the remote cause of all its motion however long continued, but the proximate cause of no motion except that which took place at the first instant. The motion at any subsequent instant is proximately caused by the motion which took place at the instant preceding. . . . It is obvious that this state of position is merely a case of the composition of causes. A cause which continues in action must in a strict analysis be considered a number of causes exactly similar, successively introduced, and producing by their combination the sum of the effects, which they would severally produce if they acted singly." The continuation of the cause then influences the effect only by adding to its quantity. If we use such a point of view the question of weight-bearing can easily be cleared up. Let us assume that weight or at least asymmetrical weight-bearing is a remote cause of lateral curvature. Now as weight is always present, and asymmetry once begun may be supposed to continue, then

weight-bearing also becomes a permanent cause. We may then refer to weight as a remote cause which is permanent and hence progressive in its effect. In order to be more explicit, we turn to the diagrams illustrating this point (Figs. 1, 2 and 3). We indicated the superincumbent weight as shown and assume that it is sufficient to produce the deformation, or at least that its influence is added to any other remote cause which produces deformation. But immediately at the point of beginning deformation the succeeding phenomena in the deformation mechanics take place according to the usual formulæ; thus

How weight-bearing enters in.

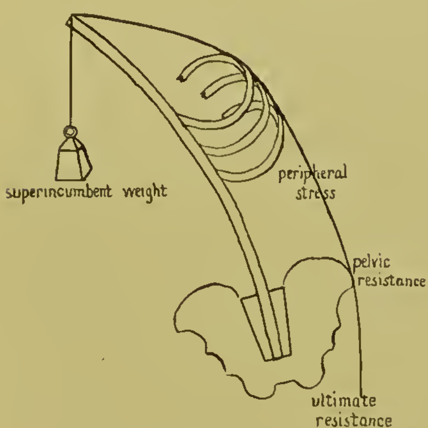

Fig. 1.
Deformation.

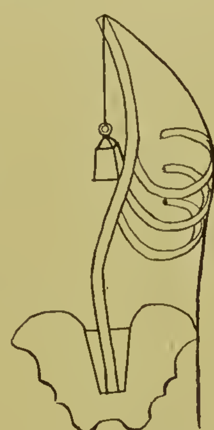

Fig. 2.
Partial recovery.

Fig. 3.
Total recovery.

following diversion of the torso, the body reacts according to the laws of the tendencies and the ribs contract on the side under tension as a result of peripheral stress, causing retrogression of the vertebræ and approximation of the lateral rib wall to the column. Then with recovery and the maintenance of these deformities, scoliosis develops and the segmented parts must adapt themselves according to their weight around the line of support. Now weight-bearing continues and the effect is repeated, thus we have what Mill styles a progressive effect. So if we classify weight-bearing as an original agent or cause which is permanent, and recognize its progressive effect there should be no confusion in comprehending these views.

In connection with this subject, a conversation with Mr.

Mickey made the point of view quite clear. Mr. Mickey asked us the following question: "According to your mechanical hypothesis, would a patient lying on his back and diverted to one side for a prolonged period acquire scoliosis?" This of course would mean that a patient is pictured in a condition in which postural tendencies would be active and yet in which superincumbent weight need not be considered, as it is not present. We answered the question as follows: "If the patient lies down and is diverted, say into a side bend, the deformation mechanics must hold good according to our hypothesis, for if that patient is thus placed upon his back and held in the asymmetrical position for a long period, the changes in the ribs and vertebræ must take place according to the laws of peripheral stress, and once the limits of elasticity are overstepped the patient gets into structural equilibrium even as he lies there. Moreover, the patient is in final equilibrium because he is lying down and the second equilibration in which a segment must become adaptable to others for purposes of functional balance need not be considered. But if following deformation in the recumbent position the patient should arise, then the thorax must readjust itself according to its weight around the line of gravity." So we believe that Mr. Mickey's question ought to be answered in the affirmative, namely, that a patient lying down can get scoliosis if he eventually gets up, but if he lies down permanently he only acquires deformation without the mechanics of recovery. The question is one which clears up our point of view quite pertinently for it shows exactly when and where static conditions enter.

In a word, then, weight enters into the deformation mechanics like any other remote cause, but one which is progressive in its effect because it is permanent, and in the recovery mechanics it is that constant quality of substance necessitating the balance of superimposed parts, as is implied in the very term balance.

How Physical Laws are Modified by Conditions of Growth and Development.

In our third paper we assume that bone, whether living or dead, would always be answerable to fundamental mechanical laws

and that the living substance like any other substance would rearrange itself in the direction of diminished resistance until a new balance is established. Having based our hypothesis on that law, it may be well to dwell upon its significance for a short space. That there is sufficient authority to uphold the principle there can be no question. The work of Julius Wolff was based upon it as a fundamental postulate and other classical works have tried to show that the proper understanding of many of the principles of the living organism and its reactions are answerable to such a law. Now, as it is recognized that bone will grow and develop according to the strain imposed, adapting its shape and structure accordingly, we should expect to see bone thicken in mass or density in the path of strain. We must always remember, however, that such thickening is only a trophic modification which takes place locally to equilibrate against stress. As a direct result of some vicious forces no such provision of nature may be possible, for the first necessity is that it arranges itself in the direction of diminished resistance, according to mechanical requirements. An important example is the wedging of vertebræ. Following a deformation stress, the general shape of the column must adapt itself to the deformation. Taken as a whole that column will finally take a bend and the bone in the column or individual vertebræ must adjust itself to that bend (Wolff): hence we get wedging of vertebræ, and in spite of the increased strain on the concave side of the column, the apparent suggestion is that of disappearance of part of the bone on that side. But whether or not the structural density increases in the path of such stress will depend purely on how well the substance has equilibrated itself to the stress. The whole subject is admirably stated in the words of Spencer: "Any force falling on any part not adapted to bear it, must either cause local destruction of tissue, or must, without destroying the tissue, continue to change it until it can change it no further; that is, until the modified reaction of the part has become equal to the modified action. Whatever the nature of the force this must happen. If it is a mechanical force, then the immediate effect is some distortion of the part—a distortion having for its limit that attitude in which the resistance of the structure to

further change of position, balances the force tending to produce the further change; and the ultimate effect, supposing the force to be continuous or recurrent, is such a permanent alteration of form, or alteration of structure, or both, as establishes a permanent balance."

The Relation of Previously Expressed Views to those of Other Men.

We cannot close this series of papers without making specific reference to certain theories of the past and explaining how they bear upon ours. Following is a brief review of a few of the important works dealing with the mechanics of lateral curvature:

Perhaps the earliest noteworthy attempt to explain the distortions of scoliosis on a mechanical basis was that made by Dods. He tried to show that all cases of lateral curvature could be most easily comprehended as taking place from a twist in the column because the normally kyphotic curve of the dorsal spine would be rendered into a lateral curve by the assumption of such a twist. So Dods was perhaps the first who tried to show the relation between normal posture and the pathological condition. He does not, however, attempt to explain the deformation of ribs nor does he investigate the question of rotation of the bodies.

An interesting work appeared by Harrison in 1842, in which he seemed to make some distinction between the cause and the mechanics. He says: "It must be observed that many disfigurations of the shape are to be attributed ultimately to phenomena of pure mechanics, although their first cause may be of a different kind." "In fact," he says, "we attribute these deformations to want of equality of power which ought to have existed between the muscles of the back having attachments to various parts of the spinal column and exerting an action on the body." These words are very expressive, but significant as the work is, it is deficient in specific reference to mechanical agencies.

Huter aroused considerable discussion in 1865 when he advanced the theory that distortions of the scoliotic could be readily explained on the grounds of inequality of growth in the two sides of the chest. He tried to show that the fetal chest differed from

that of the adult in that the former develops anteriorly while the latter develops laterally. From these grounds he inferred that when a patient displays fetal characteristics on the one side and adult characteristics on the other, then the result must be scoliosis.

This theory is not a strictly mechanical theory but we refer to it because it is the only non-mechanical theory for scoliosis which attracted much attention.

We must here mention a series of so-called pressure or weight-bearing theories of which Volkmann was the chief exponent. The theme of all these was that unequal weight-bearing caused alteration of normal growth and unequal formation of bone, and that at the point of that abnormal pressure there takes place resorption and bone atrophy. So far as the changes in the bone go according to that theory, Julius Wolff has met the chief arguments, for he showed, that the inner architecture of the bone if it corresponds to lines of stress, could not be explained on the grounds of pure weight-bearing; but whether Julius Wolff succeeded or not on disproving the theory on those grounds the question of weight-bearing is of the greatest significance and some other arguments ought to be met. We have already stated what part weight-bearing takes, according to our point of view, namely, that in deformation it acts as a remote cause (one among others) progressive in its effect, because it is permanent, and that in recovery it is that constant quality of substance requiring balance. That superincumbent weight is not necessary to produce deformation requires no argument, for deformation has been produced in quadrupeds by artificial experiments (Arndt and others). But, as animal scoliosis is not human, it has been argued that it might act directly as a downward gravitating force and thus as a primary distorting agency in the column. This we hardly believe reasonable, for if it in itself could produce a distortion of the column, then why is it that all distortions of the column which are seen except those following inherent diseases (such as Pott's disease) are in some way associated with asymmetry. The adherents of the weight-bearing theory can point to no case where the spinal column gives way under superincumbent weight, as

such, unless there is some lateral bending going on at the same time. But they have stated that they will admit that the lateral bend is always present, but that it is due to the presence of physiological curves or to the peculiarity of articular facets in the column. Or they have stated that primary lateral bend due to faulty weight-bearing might cause the condition. We simply state (and we will return to this subject again) that we do not believe such theories are capable of satisfactorily explaining all the distortions, and especially those of the thorax.

A mechanical theory of great note was advanced by Meyer in 1856. He based his theory on the hypothesis that the essential part of the column was the row of bodies while the row of arches was secondary in its movements. He believed that the two rows acted differently under pressure and compared them to two kinds of springs, stating that the row of bodies would compress according to one formula and the row of arches according to another. In this way he explained the rotation of the vertebræ. The distortions of the ribs were in part secondary to those of the column. He seemed to pay some attention to peripheral stress although he did not refer to that stress as such. The lateral resistance necessary to explain the distortion of the ribs according to his theory is due to the close connection of adjacent ones. We find great difficulty in comprehending some of Meyer's arguments and cannot understand why the renowned anatomist did not use more of his inductions on the unity of the muscular system of the trunk which he set forth so forcefully in his physiological anatomy and which has been so suggestive to ourselves. Nevertheless, we must recognize that many of the essential points as he develops them are finely reasoned and based on an accurate knowledge of functional anatomy.

The views of Riedinger on the mechanics of lateral curvature are of great interest. The essential point is that he distinguishes between the static and the dynamic influences of disfiguration. A detailed account of his theory will hardly be required at present. Suffice it to say that he bases his deductions on a comparison of the spinal column with an elastic stave, weighted at its upper end by the head. The author's views are clear and forcible, but, it

will be noted, are founded on considerations of central stress alone. He makes but little attempt to explain the changes in the ribs. So we believe that to explain the changes best, according to his theory, he must take into consideration the peripheral stress implied in the dynamic influence which he is willing to assume at the start.

Schultess recognizes the following factors of the mechanics: (1) The resistance of materials of the column and the inherent strain, elasticity, compactness and shape. (2) The body weight and its force. (3) Muscular tension. (4) Incidental loads. In the development of the deformity he distinguishes two phases—changes in the form and structure directly following mechanical influence and secondary changes in the reaction of the body following the change in form. We recognize a similar distinction when we separated the changes of deformation and recovery.

Then we must refer to the important work of Lovett, who placed the whole matter on a more comprehensive basis by laying special emphasis on the relation of normal posture to pathological conditions as shown in living normal model and the cadaver. He was the first to attempt to establish "Formulæ of Posture" a term which we have borrowed. The method of our own work is somewhat different from his but the substance of our conclusions is in a measure similar. Our chief point of departure from Lovett is that his formulæ of posture are deduced from movements of the column as regarded by itself, whereas we have regarded the skeleton as a whole, referring especially to the importance of its peripheral parts.

Finally, we ought to mention such noteworthy works at those of Albert, Lorenz, Judson, Henke, Herth, and Schanz. The views of these are, however, so closely related to others which we have mentioned that they require no further elaboration. It will be noted that almost all draw their deductions according to formulæ of central stress. Classing weight-bearing theories with central stress theories, we must emphasize that even if such theories are reasonable, peripheral strain cannot be disregarded, and even if we concede that the central stresses are the primary ones, the consideration of the body as a whole must imply the acknowledg-

ment of strain in the peripheral skeleton. We have already discussed the interdependence of central and peripheral stress, either one of which may be regarded as reciprocal to the other, so from this point of view some of the central stress theories may in a measure be regarded as just the reverse of ours.

We wish, therefore, to claim no important priority for our hypothesis, preferring to have the work regarded as an evolvement from past views rather than an original conception. But we do insist on laying emphasis on four basic points which have guided us in our work: (1) That the cause may reasonably be separated from the mechanics. (2) That there seems to be sufficient evidence in the normal to lay grounds for a reasonable hypothesis (formulæ) as to the disfiguration of the abnormal. (3) That deductions ought to be drawn from the body regarded as a whole and not from the column alone, because peripheral stresses are essential for the comprehension of the phenomena. (4) That the body so studied reveals the thoracic changes as most significant, because the results of peripheral stress seem to be permanently impressed on the rib walls.

Final Statement.

In closing, it is well to state that we realize how weak and inconclusive much of our argument has been. The objections which may be advanced we consider very grave. Certain theories which are at variance with ours are unquestionably very strong. Even if we have deduced the nature of the stresses correctly, we confess we have no right to assume that these stresses are sufficient in quantity to cause actual distortion. Indeed, to prove such a theory as this would require either mathematical calculation or the evidence of carefully conducted animal experiments. If we could have measured such strains mathematically we would have done so, but the problem was beyond us and the best we could do was to demonstrate mechanical models, making our views at least as clear as possible.

As to animal experimentation, we hoped at one time to get some results by that means; so far, however, we have not been able to plan experiments which could seem to avail us, because in order

to prove this theory by this means we should have to conduct animal experiments so that the antecedent conditions are just those which we lay down as proximate causes. Simply to take an animal and hold him in a position of asymmetry for a long time, may indeed produce deformation and the distortions may be similar to scoliosis, but how could it be inferred therefrom whether the stresses correspond to those of our formulæ? Moreover, experiments on quadrupeds are unsatisfactory because the influences due to balance are different from those on human beings.

As to monkeys, fowls and the like, there is some hope of proving or disproving our views from these, although we have not yet devised proper means for conducting such experiments so that deductions may be fairly drawn. Perhaps at some future day the work will be taken up. With regard to experiments of the past such as were carried out by Wullstein, Arnd, Ottendorff and others, although these experimenters produced distortions, we have no means of determining from their observations that the forces causing the condition correspond to the forces producing distortions in human beings. They used retaining apparatus or exsected pieces of muscle, or divided nerves, thus supplying antecedents which are never present or at least not present in the same way in human beings. The actual findings of the older experiments are, however, not at all at variance with any principles that we have expounded; we simply admit that they are neither apropos of what we are trying to prove nor are they in themselves sufficient to supply a reasonable hypothesis.

After all is said, we must recognize that in the human subject there is much of the value of an ordinary animal experiment. Thus when we note scoliosis following a lesion of the cord, or a congenital anomaly or any demonstrable cause, then we are dealing with antecedents which are readily comprehended. Even if further confirmation is lacking, the deductions which we are able to make must not be considered the less important. The only difference between such observations and animal experiments is that in the one, the antecedents are prepared by nature, and in the other by man.

Finally we may state that if it is with a keen knowledge of

shortcomings and limitations that we present this hypothesis, the fact that it is only a hypothesis will be sufficient excuse. Our aim has been to offer an explanation which is reasonable, but that it is an established theory, we make no claim.

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